DEVELOPMENT AND EVALUATION OF A SMARTPHONE APPLICATION TO PROMOTE EARLY CHILDHOOD ORAL HEALTH EDUCATION

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A thesis submitted to the faculty at the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Master of Science in Dentistry in the UNC Adams School of Dentistry (Pediatric Dentistry).

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ABSTRACT

Amanda Ashley Allen: Development and Evaluation of a Smartphone Application to Promote Early Childhood Oral Health Education
(Under the direction of Rocio Quiñonez)

Educational technologies offer opportunities to enhance learning and outcomes in pediatric dental education. This project aimed to develop an instructional smartphone application (app) and determine its acceptability and effectiveness for early childhood oral health education.

App design followed established processes. Participants for evaluation were 64 third-year dental students, randomly allocated to two groups, with assessment at two time points. Level of significance set at $p<0.05$.

In all examined learning outcome domains, substantial improvements were evident in the app group, whereas positive changes of smaller magnitude were found in the control group. Gains in certain constructs (knowledge acquisition, comfort, and clinical reasoning) were significantly higher in the app versus the control group. Most students commented favorably on smartphone app utility and functionality.

Dental students perceived smartphone app-based education positively. Its educational benefits with regards to knowledge acquisition, comfort, and clinical reasoning are superior compared to a control, article review-based, instructional approach.

To my husband, Mike,
our children, and the entire Allen family
for their patience and support, encouragement,
and unconditional love.

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LIST OF ABBREVIATIONS

AAP	American Academy of Pediatrics
AAPD	American Academy of Pediatric Dentistry
ADEA	American Dental Education Association
bOHP	Baby Oral Health Program
CODA	Commission on Dental Accreditation
ISO	International Organization for Standardization
IEC	International Electrotechnical Commission
SCT	Script Concordance Testing
UNC	University of North Carolina

CHAPTER I: INTRODUCTION

National medical and dental guidelines call for the age 1 dental visit as a way to promote early childhood oral health promotion, including trauma prevention and management.[1–5] With approximately 20 million children ages 0-5 years in the United States,[6] there is an inadequate number of pediatric dental specialists to handle this volume of patients needing care. General dentists, in the United States, provide the greatest safety net for young children, as they outnumber pediatric specialists by roughly 20:1.[7] However, barriers exist that prevent general dental practitioners from seeing the infant/toddler population, including insufficient training.[8] Dental education is influential in molding the future workforce,[9–12] raising the question of how best to educate the next generation of dental providers to promote early childhood oral health care.

Millennials, which make up the majority of the current dental student population, have grown up constantly engaged,[13] always being connected to the internet,[14] and they prefer experiential and engaging learning in an interactive environment.[13,15] If educators want to connect with this population of students, utilization of technology as a teaching and learning tool will be imperative.[16,17] The American Dental Education Association (ADEA) and the Commission on Dental Accreditation (CODA) speak to evolving curriculum that embraces critical thinking and problem-solving. CODA has set a standard in pre-doctoral dental education for competency in those skills and indicate the use of prospective simulations in which students perform decision-making as a manner to demonstrate compliance.[18] With millennial learning preferences, technology is a way to increase both training and educational efficiency.[19]

At the University of North Carolina at Chapel Hill (UNC), the Baby Oral Health Program (bOHP) was developed in 2005 as a platform to educate a generation of dental providers to be comfortable and competent at delivering preventive oral health services in early childhood.[20] With the goal of shifting trajectories of health, the development of an interactive bOHP smartphone application can continue to advance this educational platform and inspire action to improve early childhood oral health in an interactive and engaging way. This project aimed to (1) develop an instructional smartphone application (app) using bOHP as a framework and (2) determine its acceptability and effectiveness for early childhood oral health education.

CHAPTER II: REVIEW OF THE LITERATURE

2.1: Age 1 Dental Visit.

The age 1 dental visit goes hand in hand with establishing a dental home. The American Academy of Pediatric Dentistry (AAPD) encourages the establishment of a dental home by 12 months of age.[5] They recognize that the dental home should model the same principles as those of the American Academy of Pediatrics (AAP) medical home,[5] including care of infants, children, and adolescents which is accessible, continuous, comprehensive, family centered, coordinated, compassionate, and culturally effective.[21–23] The AAPD policy on the dental home further states that a dental home should provide anticipatory guidance and a plan for managing acute dental trauma.[5] A study conducted in 2002 by Nowak et al discussed the characteristics of a dental home ideally as a place that embraces children early and continues to follow them periodically through life.[24] He goes on to state that the dental home may begin in the office of a pediatric dentist and then move to that of a family practitioner, once the child has matured and is more comfortable being treated by the parents' dentist.[24] However, if a general dentist was comfortable treating this young population from the start, it would be a mutually beneficial relationship; the patient gets continuity of care and the practitioner acquires a new patient around age 1 and keeps him/her for their lifetime.

2.2: Barriers for Care.

Some general dental practitioners do not see infants and toddlers in their clinical practice. Common barriers cited in the literature include their dental practice not being geared towards children,[25] not being up-to-date on current academy guidelines,[26] lack of confidence in providing preventive services for infants and toddlers,[26] financial considerations,[8] and training.[8,26]

Insufficient training

Rich (2006) concluded that dental education is not preparing general dentists to treat children.[9] His study showed that 85% of the general dentists surveyed did not feel prepared to treat the under three population with only 40% of the respondents reporting that their undergraduate dental education had prepared them and only a third indicating that their clinical experiences during dental school had prepared them well to treat children.[9] Long (2014) indicated that boosting confidence among general dentists in providing care for infants and toddlers will require more educational experiences with this age group during dental school training.[26] McQuistan et. al (2005) supported this idea whereby dentists reporting adequate training in treating children during dental school were more likely to care for children in their practices.[27] Studies by Casamassimo and Seale have shown that U.S. pediatric dentistry pre-doctoral programs had limitations within their patient pools that adversely affected competency and clinical training for the dental students.[28,29] Rutkauskas (2015) validated these findings identifying inadequacies in pre-doctoral education as factors in general dentists' unwillingness to treat certain populations of children and confirmed that many recent dental school graduates may be entering clinical practice without skills needed to provide care to children.[30] Given the gaps in dental education, the question then becomes how best to educate the next generation of dental providers in caring for young children.

2.3: Dental Education.

Broad questions regarding dental education are currently under examination at ADEA through the "Advancing Dental Education in the 21st Century" project. The ultimate goal of this project is to develop practical strategies to address long-range challenges in dental educational institutions related to many areas, including curriculum.[31] Fontana et. al (2017) speaks to the need to delineate educational outcomes and characteristics of the needed graduate as the first step

in educating and training the ideal practitioner.[17] She further comments that two of benchmarks of student learning will be critical thinking and problem-solving.[17] Furthermore, Fontana remarks that "a focus on learning to critically think and problem-solve in any discipline, especially across disciplines and professions, requires a different way of teaching and assessment."[17]

CODA further embraces this idea. Their Accreditation Standards for Dental Education Programs highlight the importance of the application of technology within the Educational Environment.[18] Two of the standards set by CODA for pre-doctoral dental education include competency in critical thinking and problem solving and competency within the scope of general dentistry to patients in all stages of life.[18] An example given by CODA of how to demonstrate compliance for the critical thinking standard is the use of prospective simulations in which students perform decision-making.[18] The use of patient simulation would allow dental students to hone their critical thinking and problem-solving skills and give them more exposure to clinical concepts not focused on during pre-doctoral pediatric dental education.

2.4: Millennials & Technology.

Currently, the majority of the dental student population consists of millennials, individuals born between early 1980s and early 2000s. This generation is molded by events and societal trends unique to their place in history which shapes their work ethic, their thirst for knowledge and influences both teaching and learning.[32–35] Millennials are described as digital natives,[36] technologically savvy,[32] and many view technology as a "defining characteristic of their generation."[14,34] Utilization of technology will be important,[16,17] as educator's often have limited time to deliver curricular content and require effective modes to deliver such pedagogy.[19]

Technology-enhanced simulation is an educational tool that students interact with to gain and assess skills through repeated practice within a safe environment for the purpose of teaching

or assessment.[37,38] Meta-analyses conducted in 2011 and 2012 indicated in health professions education, technology-enhanced simulation training is "consistently associated with better learning outcomes, with larger effects for outcome of knowledge, skills and behaviors when compared to no intervention and other traditional modalities." [39,40]

2.5: Baby Oral Health Program.

In 2005, bOHP was developed at UNC as a platform to educate a generation of dental providers to be comfortable and competent at delivering preventive oral health services in early childhood.[20] With the goal of shifting trajectories of health, the development of an interactive bOHP smartphone application (app) can continue to advance this educational platform and inspire action to improve early childhood oral health in an interactive and engaging way.

2.6: Development of a Smartphone Application.

Mobile devices are being used as a platform in the educational sector.[41] Developing an app starts with a concept and moves to sketching and wireframing prior to creating a prototype and adding design elements.[42,43] Decisions are made about native app versus mobile web app and understanding the technical aspects of platform and format requirements prior to finishing the development process.[42] A key component of a successful educational application is usability, which includes learnability, ease of use, efficiency and effectiveness.[41]

A validated systems and software engineering standard, prepared and published by the International Organization for Standardization/International Electrotechnical Commission (ISO/IEC 25010:2011), defines two models applicable to all software products and computer systems.[44–46] The product quality model is composed of characteristics related to when the software is in the development stage and the quality in use model addresses quality when the software is used in the operational stage.[44–46] Usability can be found within the eight characteristics listed for the product quality model, which is further broken down into sub-

characteristics to include learnability, operability, and user interface esthetics.[44–46] Effectiveness, efficiency and usefulness are found within the five characteristics and sub-characteristics of the quality in use model.[44–46]

Usability testing of your target audience helps with refinement of your ideas prior to implementation and ensures that you will meet their needs and expectations.[47,48]

Aims of Study.

This project aimed to (1) develop an instructional smartphone application (app) using bOHP as a framework and (2) determine its acceptability and effectiveness for early childhood oral health education.

Development Aims

- Assess dental student preferences to facilitate student learning and enhance their experience regarding early childhood oral health.
- Develop a smartphone app using bOHP as a framework simulating a patient experience involving fundamental tenets of early childhood oral health with a focus on primary tooth trauma.
- Determine the app's acceptability by learners of different levels.

Evaluation Aims

- Measure the smartphone app's impact on knowledge acquisition, clinical reasoning, comfort and stage of readiness to care for young children.
- Determine superiority of app-based versus article-based learning.
- Obtain feedback on dental student's perceptions of the smartphone app's utility to gain insight into use of technology as an educational tool.

Null Hypotheses

- There is no difference in clinical reasoning and knowledge acquisition based on the interactivity of the smartphone application.
- The smartphone application has no benefit and no change will be seen in comfort and stage of readiness to see young children in clinical practice.

REFERENCES

1. Perinatal and infant oral health care. Pediatr Dent. 2017 Sep 15;39(6):208–212.

2. Oral Health Assessment Policy [Internet]. [cited 2018 Feb 21]. Available from: http://www.aaphd.org/oral-health-assessment-policy

3. Statement on Early Childhood Caries [Internet]. [cited 2018 Feb 21]. Available from: https://www.ada.org/en/about-the-ada/ada-positions-policies-and-statements/statement-on-early-childhood-caries

4. Section On Oral Health. Maintaining and improving the oral health of young children. Pediatrics. 2014 Dec;134(6):1224–1229.

5. American Academy on Pediatric Dentistry Council on Clinical Affairs. Policy on the Dental Home. Pediatr Dent. 2018 Oct 15;40(6):29–30.

6. Howden LM, Meyer JA. Reproduction of the Questions on Sex, Age, and Date of Birth From the 2010 Census [Internet]. United States: U.S. Census Bureau; 2011 May [cited 2018 Feb 21] p. 1–16. Report No.: C2010BR-03. Available from: https://www.census.gov/prod/cen2010/briefs/c2010br-03.pdf

7. Professionally Active Dentists by Specialty Field | The Henry J. Kaiser Family Foundation [Internet]. [cited 2018 Feb 22]. Available from: https://www.kff.org/other/state-indicator/dentists-by-specialty-field/?currentTimeframe=0&selectedRows=%7B%22wrapups%22:%7B%22united-states%22:%7B%7D%7D,%22states%22:%7B%22north-carolina%22:%7B%7D%7D%7D&sortModel=%7B%22colId%22:%22Pedodontist%22,%22sort%22:%22desc%22%7D

8. Garg S, Rubin T, Jasek J, Weinstein J, Helburn L, Kaye K. How willing are dentists to treat young children? The Journal of the American Dental Association. 2013 Apr;144(4):416–425.

9. Rich JP, Straffon L, Inglehart MR. General dentists and pediatric dental patients: the role of dental education. J Dent Educ. 2006 Dec;70(12):1308–1315.

10. Dao LP, Zwetchkenbaum S, Inglehart MR. General dentists and special needs patients: does dental education matter? J Dent Educ. 2005 Oct;69(10):1107–1115.

11. Smith CS, Ester TV, Inglehart MR. Dental education and care for underserved patients: an analysis of students' intentions and alumni behavior. J Dent Educ. 2006 Apr;70(4):398–408.

12. Vishnevetsky A, Mirman J, Bhoopathi V. Effect of advocacy training during dental education on pediatric dentists' interest in advocating for community water fluoridation. J Dent Educ. 2018 Jan;82(1):54–60.

13. Price C. Why Don’t My Students Think I'm Groovy?: The New “R”s for Engaging Millennial Learners. In: Meyers SA, Stowell JR, editors. Essays from e-xcellence in teaching. 2010. p. 29–34.

14. Millennials: Confident. Connected. Open to Change | Pew Research Center [Internet]. [cited 2018 Apr 19]. Available from: http://www.pewsocialtrends.org/2010/02/24/millennials-confident-connected-open-to-change/

15. Skiba DJ, Barton AJ. Adapting your teaching to accommodate the net generation of learners. Online J Issues Nurs. 2006 May 31;11(2):5.

16. Stuart G, Triola M. Enhancing Health Professions Education through Technology: Building a Continuously' ' Learning Health System. In: Larson T, editor. Proceedings of a conference sponsored by the Josiah Macy Jr Foundation in April 2015. New York: Josiah Macy Jr. Foundation; 2015.

17. Fontana M, González-Cabezas C, de Peralta T, Johnsen DC. Dental education required for the changing health care environment. J Dent Educ. 2017 Aug;81(8):eS153–eS161.

18. Commission on Dental Accreditation. Accreditation Standards For Dental Education Programs. 2018;1–38.

19. Global Forum on Innovation in Health Professional Education, Board on Global Health, Institute of Medicine, National Academies of Sciences, Engineering, and Medicine. Envisioning the future of health professional education: workshop summary. Washington (DC): National Academies Press (US); 2016.

20. About bOHP [Internet]. [cited 2018 May 10]. Available from: http://www.babyoralhealthprogram.org/index.php/about/page/11/Why+bOHP

21. Medical Home Initiatives for Children With Special Needs Project Advisory Committee. American Academy of Pediatrics. The medical home. Pediatrics. 2002 Jul;110(1 Pt 1):184–186.

22. American Academy of Pediatrics Council on Children with Disabilities. Care coordination in the medical home: integrating health and related systems of care for children with special health care needs. Pediatrics. 2005 Nov;116(5):1238–1244.

23. Britton CV, American Academy of Pediatrics Committee on Pediatric Workforce. Ensuring culturally effective pediatric care: implications for education and health policy. Pediatrics. 2004 Dec;114(6):1677–1685.

24. Nowak AJ, Casamassimo PS. The dental home: a primary care oral health concept. J Am Dent Assoc. 2002 Jan;133(1):93–98.

25. Seale NS, Casamassimo PS. Access to dental care for children in the United States: a survey of general practitioners. J Am Dent Assoc. 2003 Dec;134(12):1630–1640.

26. Long CM, Quinonez RB, Rozier RG, Kranz AM, Lee JY. Barriers to Pediatricians' Adherence to American Academy of Pediatrics Oral Health Referral Guidelines: North Carolina General Dentists' Opinions. Pediatric Dentistry. 2014;36(4):309–315.

27. McQuistan MR, Kuthy RA, Damiano PC, Ward MM. General dentists' referral of children younger than age 3 to pediatric dentists. Pediatr Dent. 2005;27(4):277–283.

28. Casamassimo PS, Seale NS. Adequacy of patient pools to support predoctoral students' achievement of competence in pediatric dentistry in U.S. dental schools. J Dent Educ. 2015 Jun;79(6):644–652.

29. Seale NS, Casamassimo PS. U.S. predoctoral education in pediatric dentistry: its impact on access to dental care. J Dent Educ. 2003 Jan;67(1):23–30.

30. Rutkauskas J, Seale NS, Casamassimo P, Rutkauskas JS. Preparedness of Entering Pediatric Dentistry Residents: Advanced Pediatric Program Directors' and First-Year Residents' Perspectives. J Dent Educ. 2015 Nov;79(11):1265–1271.

31. Bailit H, Formicola A. Introduction to "advancing dental education in the 21st century" project. J Dent Educ. 2017 Aug 1;81(08):1004–1007.

32. Mangold K. Educating a New Generation: Teaching Baby Boomer Faculty About Millennial Students. Nurse Educ. 2007;32(1):21–23.

33. Major JAH. Beyond the blackboard: Basics of generational learning. Surgical services management. 2002;8(3):51.

34. Blue C, Henson H. Millennials and dental education: utilizing educational technology for effective teaching. J Dent Hyg. 2015 Feb;89 Suppl 1:46–47.

35. Pastorino E. Chapter 4: When Generations Collide in the Classroom. In: Saville B, Zinn T, Meyers S, Stowell J, editors. Essays from E-xcellence in Teaching, 2006. Society for the Teaching of Psychology Web site: http://teachpsych.org/resources/ebooks/eit2006/eit2006.php; 2007. p. 16–19.

36. Millennials in Adulthood | Pew Research Center [Internet]. [cited 2018 Apr 19]. Available from: http://www.pewsocialtrends.org/2014/03/07/millennials-in-adulthood/

37. Kneebone R. Simulation in surgical training: educational issues and practical implications. Med Educ. 2003 Mar;37(3):267–277.

38. Cook DA, Hamstra SJ, Brydges R, Zendejas B, Szostek JH, Wang AT, et al. Comparative effectiveness of instructional design features in simulation-based education: systematic review and meta-analysis. Med Teach. 2013;35(1):e867–898.

39. Cook DA, Hatala R, Brydges R, Zendejas B, Szostek JH, Wang AT, et al. Technology-enhanced simulation for health professions education: a systematic review and meta-analysis. JAMA. 2011 Sep 7;306(9):978–988.

40. Cook DA, Brydges R, Hamstra SJ, Zendejas B, Szostek JH, Wang AT, et al. Comparative effectiveness of technology-enhanced simulation versus other instructional methods: a systematic review and meta-analysis. Simul Healthc. 2012 Oct;7(5):308–320.

41. Ali A, Alrasheedi M, Ouda A, Capretz LF. A Study of The Interface Usability Issues of Mobile Learning Applications for Smart Phones from the User's Perspective. IJITE. 2014 Dec 31;3(4):1–16.

42. What Are The Various Phases Of Mobile App Development? [Internet]. [cited 2020 Mar 10]. Available from: https://medium.com/swlh/what-are-the-various-phases-of-mobile-app-development-4f0a1748e619

43. Mobile App Development Process: A Step-by-Step Guide | Invonto [Internet]. [cited 2020 Mar 10]. Available from: https://www.invonto.com/insights/mobile-app-development-process/

44. García-Mireles G. Identifying relevant product quality characteristics in the context of very small organizations. ComSIS. 2016;13(3):875–900.

45. Schneider F, Berenbach B. A literature survey on international standards for systems requirements engineering. Procedia Computer Science. 2013;16:796–805.

46. Suitability F. Product Quality - ISO/IEC 25010 [Internet]. [cited 2018 Jul 1]. Available from: https://edisciplinas.usp.br/pluginfile.php/294901/mod_resource/content/1/ISO%2025010%20-%20Quality%20Model.pdf

47. How to Conduct Usability Testing for Mobile Apps [Internet]. [cited 2020 Mar 23]. Available from: https://www.abtasty.com/blog/usability-mobile-apps/

48. Mobile App Testing is Key to Successful App Development [Internet]. [cited 2020 Mar 23]. Available from: https://usabilitygeek.com/usability-testing-mobile-applications/

CHAPTER III: INTRODUCTION

In the United States, general dentists provide the greatest safety net for young children's oral health care, as they outnumber pediatric dentists by a ratio of 24:1.[7] Barriers commonly cited for general dentists' unwillingness to care for young children include lack of confidence in providing preventive oral health care for children younger than three years old[26] and insufficient training.[8] Dental education is fundamental for molding the future workforce; however, the current system is not adequately preparing general dentists to care for children.[9–12] Rich (2006) reported that 15% of general dentists surveyed felt prepared to treat the under three population.[9] Similar concerns exist among U.S. pediatric dentistry pre-doctoral programs and the limitations within their patient pools adversely affecting student competency and clinical training.[28,29] Long (2014) indicated that boosting confidence among general dentists in providing care for infants and toddlers would require more educational experiences during dental school.[26] This raises the question of how best to educate the next generation of dental providers to promote early childhood oral health care.

Millennials make up the majority of the current dental student population. They are described as digital natives,[36] technologically savvy,[32] and prefer experiential and engaging learning in an interactive environment.[13,15] Technology has created a new literacy for education beyond reading and writing. If educators want to engage this population of students, utilization of technology as a teaching and learning tool will be imperative.[16,17] The Commission on Dental Accreditation (CODA), which sets standards for pre-doctoral dental education, recognizes the importance of applying technology within the educational environment.[18] Compliance for a standard set by CODA involving competency in critical thinking and problem-solving speaks to

the use of prospective simulations in which students perform decision-making.[18] Meta-analyses on this topic indicate in health professions education, technology-enhanced simulation training is "consistently associated with better learning outcomes, with larger effects for outcomes of knowledge, skills and behaviors when compared to no intervention and other traditional modalities."[39,40] Considering millennial learning preferences, new technologies and novel applications of existing technologies are avenues to cultivate learning, decompress didactic time, and increase both training and educational efficiency.[19]

At the University of North Carolina at Chapel Hill (UNC), the Baby Oral Health Program (bOHP) was developed in 2005 as a platform to educate a generation of dental providers to be comfortable and competent at delivering preventive oral health services in early childhood.[20] With the goal of shifting trajectories of health, the development of an interactive bOHP smartphone application can continue to advance this educational platform and inspire action to improve early childhood oral health in an interactive and engaging way. This project aimed to (1) develop an instructional smartphone application (app) using bOHP as a framework and (2) determine its acceptability and effectiveness for early childhood oral health education. Specifically, the study examined the impact of this novel educational technique's effects on knowledge acquisition, clinical reasoning, comfort, and stage of readiness to care for young children in clinical practice. Additionally, feedback on dental student's perceptions of the smartphone app's usability was obtained.

CHAPTER IV: METHODS

4.1: Study Design and Population.

This study received exempt status by the UNC Institutional Review Board (#18-0616), for both development and evaluation. Study participants were recruited from convenience samples of Adams School of Dentistry pediatric dentistry faculty, pediatric dentistry residents, two consecutive years of third-year pre-doctoral students, and a group of private practitioners, including both general dentists and pediatric specialists.

Comprehensive smartphone app development followed established processes, including evaluation and iterative revisions, using qualitative methods. Recruitment occurred at two time points during app development, first for learner testing and subsequently for pilot testing. Fifteen third-year dental students enrolled after an in-class presentation for learner testing and participated from December 2018 to January 2019. The initial version of the app was iteratively revised and lengthened. Nineteen individuals, spanning several learner levels (five third-year pre-doctoral students, five pediatric dentistry residents, five general practitioners and four pediatric dentists), enlisted for pilot testing via email. These individuals provided feedback during pilot testing, which spanned from February 2019 to April 2019. The app prototype served as the foundation for the bOHP Clinical Education App, which, once created, was pilot-tested by seven additional learners (three fourth-year pre-doctoral students, two pediatric dentistry residents and two pediatric dentistry faculty members) and edited as needed.

Emails were sent to all eighty-three members of the subsequent third-year class in September 2019 to recruit for the educational evaluation, which occurred at the end of that month. Sixty-four dental students volunteered to provide quantitative feedback and were

randomly allocated to the intervention (app) (n=31) or control (article-based) group (n=33). Study participants were surveyed the week leading up to (pre-) and at the day of testing (post-), in four domains: perceived value, knowledge, comfort, and stage of readiness to see infants/toddlers in clinical practice. Participants' clinical reasoning was assessed using script concordance testing (SCT).[49]

4.2: App Development.

App development included stages of design, planning and prototyping (Figure 1).

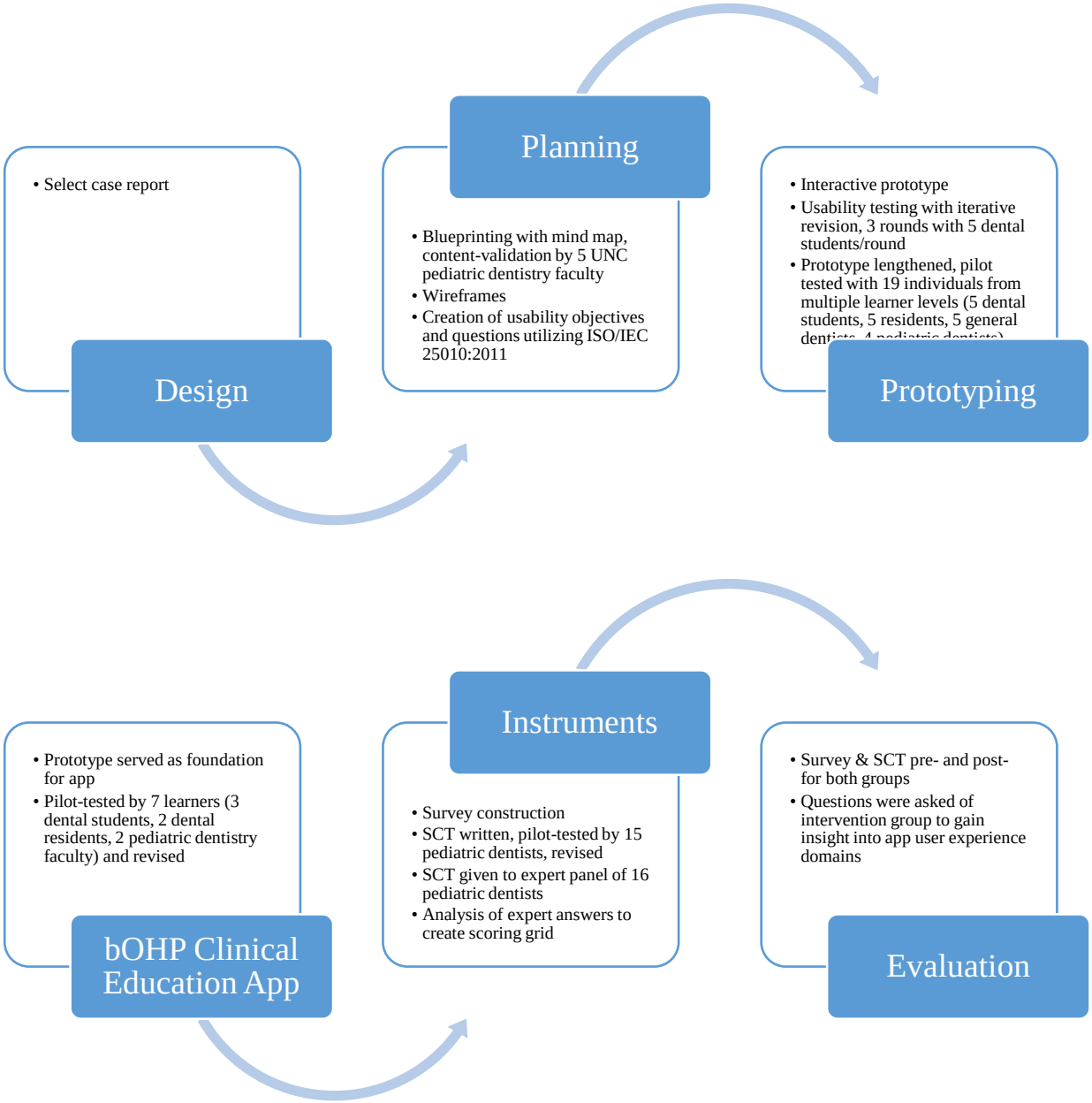


Figure 1: App development and evaluation

During the design phase, investigators visualized their concept and selected a published case report presenting the case of a 10-month-old child sustaining an avulsion of his maxillary primary central incisors.[50] In the planning phase, investigators used MindMup [51] to create the

blueprint of a storyboard with a mind map depicting the decision-making process a dentist would engage in as he/she worked through this patient encounter. Using systematic thinking, a "correct expert path" was forged with the intention of providing evidence-based guidance to the learner if he/she veered off the correct path. The completed storyboard was content-validated by five UNC pediatric dentistry faculty and subsequently converted into a static prototype using wireframes.[52]

During the planning phase, investigators utilized a validated systems and software engineering standard (ISO/IEC 25010:2011) to create test objectives and questions for usability testing. The standard defined both a product quality model (i.e. quality when the software is in the development stage) and a quality in use model (i.e. quality when the software is used in the operational stage) applicable to all software products and computer systems.[44–46] Of the characteristics given for the product quality model, four were selected to be subsequently evaluated (functional appropriateness, learnability, operability, and user interface esthetics), as they best reflected the intent of an educational application. Similarly, three quality in use model characteristics were chosen (effectiveness, efficiency, and usefulness) for evaluation.

The app prototyping began with transitioning the wireframe prototype to an interactive one via the Justinmind Prototyping tool.[53] Participating dental students evaluated a portion (initial patient encounter through diagnosis) of the functional prototype through usability testing. At the end of each round, the prototype was iteratively revised based on their feedback, and once all three rounds were completed, the case was lengthened. Pilot testing of the entire case involved multiple learner levels, with the revised prototype serving as the foundation for the bOHP Clinical Education App (Figures 2 and 3).

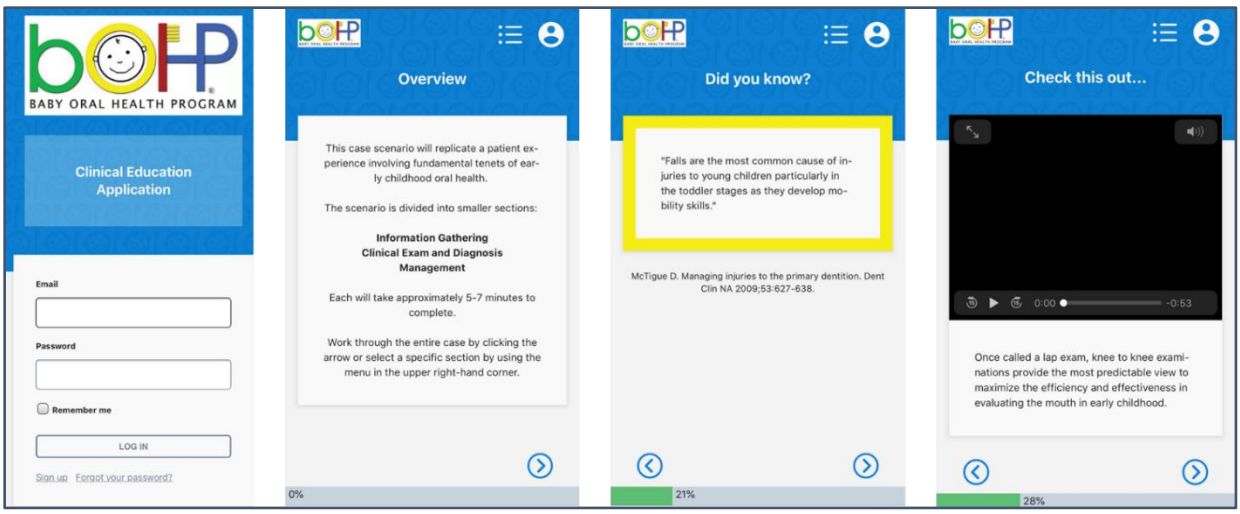


Figure 2: Examples of instructional smartphone application screens

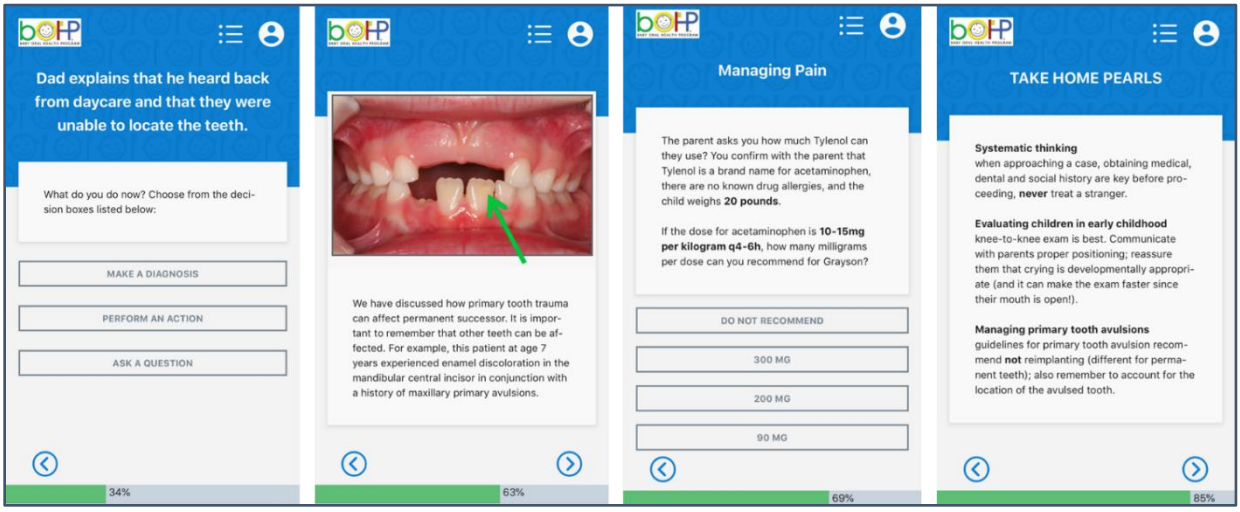


Figure 3: Examples of instructional smartphone application screens

Prototype learner testing illuminated several themes, i.e. dental students' preference for technology in their education, positive feedback for the prototype's usability, user-friendliness and intuitiveness, appreciation for the immediate feedback the prototype provided, mixed feelings about gaming and competition as well as the addition of animation versus use of static images. Ideal case length recommended by 60% (9/15) of learners was approximately 15- 20 minutes.

4.3: Assessment Procedures and Instruments.

Study participants received two instruments (a survey and a test) at two time points: first the week leading up to and second, the day of testing post-educational intervention. The survey contained close-ended items assessing aspects of the learners' experience in four domains: perceived value of app, knowledge, comfort, and stage of readiness to care for infants/toddlers in clinical practice. Subsequently, participants' clinical reasoning was objectively assessed in comparison to that of an expert panel's using SCT.[49]

Specifically, the pre-survey that all participants completed regardless of their experimental or control group allocation, included twenty-five questions in four domains: value of smartphone app (1 item), knowledge (10 items), comfort (13 items), and stage of readiness (1 item). Perceived value of a smartphone application was assessed with a single 4-point scale question, including response options that ranged between 1: "no value" and 4: "a lot of value." This different scoring scheme was purposefully used to disallow participants from expressing neutrality in this question. Knowledge questions contained only one best answer that respondents were asked to identify, and were created keeping the "remember" level of Bloom's Taxonomy in mind.[54] These questions assessed important fundamental concepts, i.e. most predictable way of obtaining an oral exam for infants/toddlers, peak age for dental trauma in the primary dentition, and which primary tooth is most likely involved. Of note, three knowledge questions were removed from the initial pool of ten items, as they were later determined as possibly favoring the application group. Comfort (5-point Likert scale) items were divided into two parts, task-specific comfort (9 items) and overall comfort (4 items), with options ranging between 1: "very uncomfortable" to 5: "very comfortable." Task-specific comfort included questions for specific clinical actions e.g. "how comfortable are you with performing a knee-to-knee exam." Overall comfort encompassed four general domains of performance: information

gathering, clinical exam, diagnosis and management of primary tooth trauma. Stage of readiness was assessed with a single 0-10 scale question: "Based on your current understanding of diagnosis and management of primary tooth trauma, would you refer a patient who had experienced primary tooth trauma to a specialist or treat the patient in your practice?" with 0 indicating referral to a specialist.

The intervention (app) group and the control (article-based) group each received a tailored post-survey. Additional questions in the intervention group assessed students' perceptions regarding the usability of the smartphone application. Two open-ended questions were also included: "What was the best thing about the smartphone application?" and "What can be done to make it better?" Closed-ended (5-point Likert scale) questions were used to gain insight in app user experience domains, i.e. app's performance, user-friendliness of the interface, suitability of images, overall appearance, and usefulness of educational content. There was also an opportunity for the study participants to provide recommendations for future educational smartphone application cases in an open-ended format.

The objective assessment of participants' clinical reasoning was done via SCT, a written scenario-based test optimal for assessing clinical reasoning under conditions of uncertainty.[49] Once the test construction was complete, fifteen pediatric dentists piloted the SCT and modifications were made based on their feedback. An additional sixteen pediatric dentists composed the expert panel for the SCT, and their answers served as the scoring grid for the participants' SCT. The test included three clinical scenarios, each with accompanying questions, for a total of 41 test items, and a theoretical score range of 0-41.

4.4: Analytical Strategy.

Variables and measures

Participants' demographics included gender (male/female), age (measured in years), self-reported dental school rank (categorized in quintiles), future career plans (enter general dental practice or pursue advanced training), and being a parent (yes/no). Domain summary scores were created for knowledge and comfort as the sums of individual item responses. The number of correct responses in the knowledge items was summed into a knowledge score (theoretical range: 0-7, wherein 0 indicates the lowest and 7 the highest possible knowledge). The numeric scale responses for comfort, for both task-specific comfort and overall comfort items (e.g. 1-5), were summed into a task-specific comfort score (theoretical range: 9-45, wherein 9 corresponds to the lowest and 45 to the higher possible comfort) and an overall comfort score (theoretical range: 4-20, wherein 4 corresponds to the lowest and 20 to the highest possible comfort). Clinical reasoning SCT scores were calculated by comparing dental students' responses to the answers given by the expert panel where the expert modal answer was credited with a full point, and partial credit was given to other answers provided by the panel members.[55] Scoring reflected the degree of concordance of the participants' judgements to those on the expert panel.

Participants' responses regarding their perceptions of the app's usability and value were grouped based on their 5-point Likert scale responses - favorable (i.e. "useful" or "very useful" or scores of 4-5), neutral ("somewhat useful" or score of 3), or unfavorable (i.e. "not useful" or "definitely not useful" or scores 1-2). Responses to the 'added value' question were dichotomized as favorable (i.e. scores 3-4) vs. unfavorable (i.e. scores 1-2). A single item (i.e. 0-10 scale) score was used to assess learners' stage of readiness. Additionally, we extracted and compared the times (in minutes) that participants spent interacting with either the application or reading the article, depending on their group allocation.

Statistical analysis

The data analysis departed from descriptive and summary statistics (i.e. proportions, means and medians) for participants' characteristics and favorable vs. unfavorable perceptions of app usability and value. Not all domain scores were distributed normally and our sample size was relatively small; for this reason, their means and standard deviations (SD) are presented for descriptive purposes. The proportion of directional changes (i.e. increased, no change, decreased) was compared between pre- and post- intervention scores using sign tests. Differences in domain score changes (i.e. rank order) were tested between the app and the control group using non-parametric Wilcoxon tests. One participant was excluded from all data analyses due to incomplete data, resulting in analytical sample sizes of 31 for the app and 32 for the control group. Three participants in the intervention group were excluded from the clinical reasoning analysis due to missing SCT scores at baseline, resulting in a comparison between 28 app compared with 32 control participants in this domain. The level of significance was set at $p<0.05$ for all comparisons and Stata 16.0 (StataCorp LLC, College Station, TX) was used for all analyses.

CHAPTER V: RESULTS

The characteristics of the study participants are presented in **Table 1**. The app and control groups were balanced; there were similar proportions of male/female participants, as well as of those planning to pursue advanced training or enter general practice. There were no significant differences in individual characteristics between the app and the control group participants. The intervention group spent significantly more time interacting with the smartphone application compared to those reading the article in the control group (24 min vs. 9 min), although 2.5 minutes of that difference was due to the required viewing of seven videos that were embedded in the app.

Table 1. Characteristics of the 63 study participants.

	app group	control group	p
Gender	n (row. %)	n (row. %)	0.5
male	13 (45)	16 (55)	
female	18 (53)	16 (47)	
Age (years)			0.2
23-25	15 (42)	21 (58)	
26-45	16 (59)	11 (41)	
mean (sd); median	26.3 (0.7); 26	26.3 (0.8); 25	1.0
Reported dental school rank			0.7
top 80%	10 (53)	9 (47)	
60-80%	11 (52)	10 (48)	
40-60%	5 (45)	6 (55)	
20-40%	4 (50)	4 (50)	
bottom 20%	0 (0)	2 (100)	
Future career plans			0.7
general practice	18 (51)	17 (49)	
advanced training	13 (46)	15 (54)	
Parent			0.7
yes	4 (57)	3 (43)	
no	27 (48)	29 (52)	

Estimates of knowledge, comfort, stage of readiness and clinical reasoning, pre- and post-intervention are presented in **Table 2**. Within each group, significant pre-post improvements

were evident in all domain scores apart from knowledge, stage of readiness and clinical reasoning in the control group (sign test p>0.05). Specifically, 24 (86% of) participants improved their clinical reasoning between pre- and post-intervention in the app group (sign test p=0.0002), whereas 14 (45% of) participants improved it in the control group (sign test p=0.8). The improvements were significantly higher in the app compared with the control group for knowledge, task-specific comfort and overall comfort domains (all p<0.05)—although participants in the app group showed more gains in the single item assessing stage of readiness than those in the control group, this difference was not statistically confirmed (p=0.2).

Table 2. Changes in the 63 study participants' knowledge, comfort, stage of readiness and clinical reasoning, overall and stratified by experimental study group.

	pre	post	proportion increased	app *versus* control difference‡
	mean (SD); median	mean (SD); median		p
Knowledge				0.0005
app group	5.2 (1.4); 5	6.8 (0.4); 7	0.77†	
control group	5.5 (0.9); 6	5.9 (0.9); 6	0.50	
Task-specific comfort				0.03
app group	30.0 (6.4); 30	34.5 (4.9); 35	0.77†	
control group	29.8 (6.0); 30.5	31.5 (5.7); 33	0.69†	
Overall comfort				0.02
app group	13.9 (2.9); 14	16.3 (2.1); 16	0.74†	
control group	14.1 (2.4); 14	15.0 (2.9); 15.5	0.59†	
Readiness				0.2
app group	4.9 (2.3); 5	5.9 (2.0); 6	0.61†	
control group	4.4 (2.3); 5	4.7 (2.6); 5	0.44	
Clinical reasoning*				0.01
app group	23.4 (4.5); 24	25.1 (4.1); 26	0.86†	
control group	23.9 (4.5); 24	24.2 (4.0); 25	0.44	

*3 participants in the intervention group were excluded from this analysis due to missing SCT scores at baseline, resulting to a comparison between 28 participants in the app *versus* 32 participants in the control group
†Denotes statistically significant proportion with improved scores between pre- and post-intervention (non-parametric sign test, P<0.05)
‡Obtained with a non-parametric Wilcoxon test

Study participants' perceptions of the educational app's usability and value in various domains are illustrated in **Table 3**. Dental students overwhelmingly rated the smartphone application favorably across all examined domains (e.g. performance, interface user-friendliness,

suitability of images and overall appearance, etc.). Favorable responses to the 'overall appearance' question were proportionally fewer (69%) among those planning to pursue advanced training compared with those planning to go into private practice (100%, p=0.02). Additionally, favorable responses to the 'deepened my interest in early childhood oral health' question were significantly inversely associated with class rank (p=0.02).

Table 3. Study participants' perceptions of the educational app's usability and value in various domains.

	favorable	neutral	unfavorable
	n (row %)	n (row %)	n (row %)
Performance	28 (90)	3 (10)	0 (0)
User-friendliness	26 (84)	4 (13)	1 (3)
Image suitability	28 (90)	2 (6)	1 (3)
Overall appearance	27 (87)	3 (10)	1 (3)
Content usefulness	30 (97)	1 (3)	0 (0)
Deepened interest in trauma	21 (67)	10 (33)	0 (0)
Deepened interest in early childhood oral health	17 (55)	12 (39)	2 (6)
Added value to dental education	29 (94)	n/a	2 (6)

In terms of open-ended, qualitative comments regarding the app, approximately half of the participants commented that its ease of use and user-friendliness were the best things about it. Twenty-two percent of participants suggested that the app could be improved by making the experience quicker by streamlining information. Other recommendations included the development of future cases including trauma in patients of different ages, a pediatric/orthodontic patient, behavior management, caries management, pathology, genetic anomaly cases or cases with congenital disorders. Ninety-seven percent of participants felt more of these types of early childhood oral health cases would help/assist in their education.

CHAPTER VI: DISCUSSION

To the best of our knowledge, this is the first study to examine smartphone app-based education in pediatric dentistry, both in development and operation. Dental education is critical in helping meet the oral health needs of all children, yet educators often have limited time to deliver curricular content and require effective modes to carry out such pedagogy. Smartphone applications are an emerging example of technology that can help address these challenges in dental education.[19] App development allowed for the ability to customize a case-based experience and focus learners to key concepts that, once mastered, would help them become more competent and confident dental providers. Evaluation demonstrated substantial improvements in all examined outcome domains in the app group, compared to smaller positive changes found in the control group. Evaluation also demonstrated an application that was well liked by virtually all students, with positive perceptions of app content, functionality, and added value to their education.

Although a first in pediatric dentistry, smartphone apps have been utilized in other health specialty areas, including medicine, nursing, and other areas of dentistry.[56–60] At the University of Florida College of Medicine, within the Department of Surgery, a smartphone app was created and found to actively engage residents and improve participation in educational activities.[56] The use of smartphones has been examined within Ophthalmology for both education and clinical use.[57,58] Nursing is evaluating smartphones and mobile apps to determine if their use could enhance clinical education.[59] Within dentistry, a mobile learning app was developed to teach clinical prosthodontics cases to dental students, and the study revealed the app was perceived

well by dental students and proved to be an effective way to improve clinical reasoning skills for planning prosthodontic rehabilitation.[60]

Bringing the bOHP platform to an interactive smartphone application could provide a mechanism that allows oral health providers at any stage of development or location to access these educational experiences, which may strengthen engagement to promote care for young children. This technology could allow for fundamental knowledge of early childhood oral health to be consumed by every dental student locally and globally, while increasing flexibility in dental student training. Future research directions include developing multiple smartphone app-based clinical cases spanning various topics in dental education and further evaluating the impact of the constructs examined in this study. Evaluating knowledge retention in the app versus article-based learning by testing at an additional time point one week post-intervention would also be informative. Additionally, one could examine smartphone app-based education and the ability to flip the classroom and decompress didactic time.

The findings of this study need to be considered in the context of its limitations. First, the smartphone app was built for a larger purpose than this study and now resides on the Baby Oral Health Program website.[61] As such, there was an assessment component at the end of the clinical case to help solidify important concepts. There was a loophole in the technological process that allowed dental students to advance into the assessment component, which possibly could have given those students an unfair advantage for knowledge acquisition. This should be considered when interpreting knowledge outcome findings. Second, this novel educational tool included only one case with only one topic. Consequently, the SCT used did not include the number of cases or questions literature has shown to garner statistical significance.[62] Third, while dental student group allocation was random, a clearly defined method for randomization was not used; therefore, the process would be very difficult to duplicate. Fourth, utilization of a

convenience sample of third-year pre-doctoral dental students from one dental school makes it difficult to generalize the findings to a larger audience. Finally, a smartphone application is not easy or quick to develop or maintain and will require regular updates to keep the evidence-based references current.

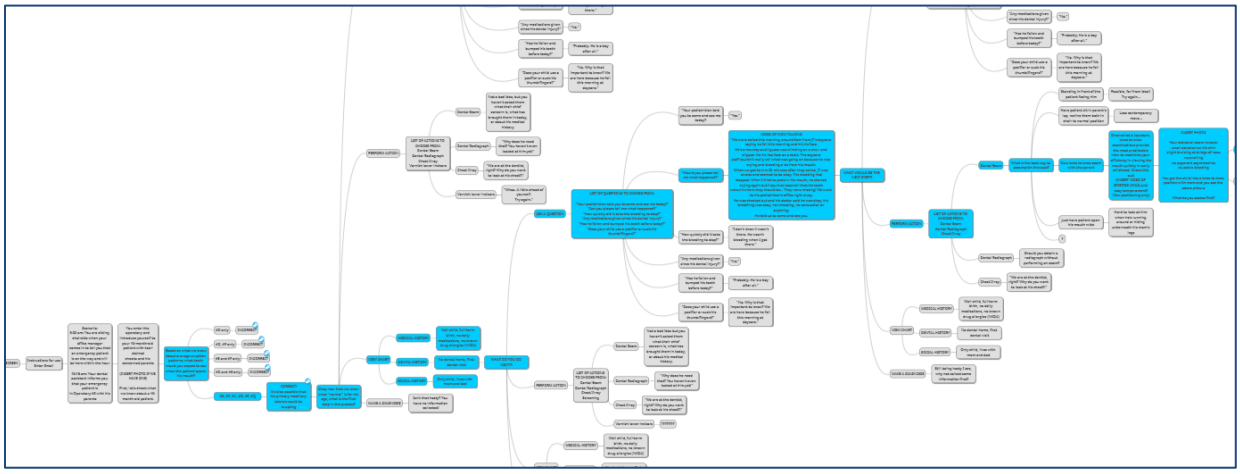
CHAPTER VII: CONCLUSION

The overarching goal of the project was to develop and evaluate the effectiveness of a smartphone app using UNC's bOHP as a framework to apply technology that facilitated learning and engaged students in early childhood oral health. This tool demonstrated promise. The study proved the concept that dental students' perceived smartphone-app based education favorably, and the educational benefits in terms of knowledge acquisition, comfort, and clinical reasoning were superior compared to an article review-based, instructional approach.

APPENDIX 1: DEVELOPMENT- PLANNING & PROTOTYPING

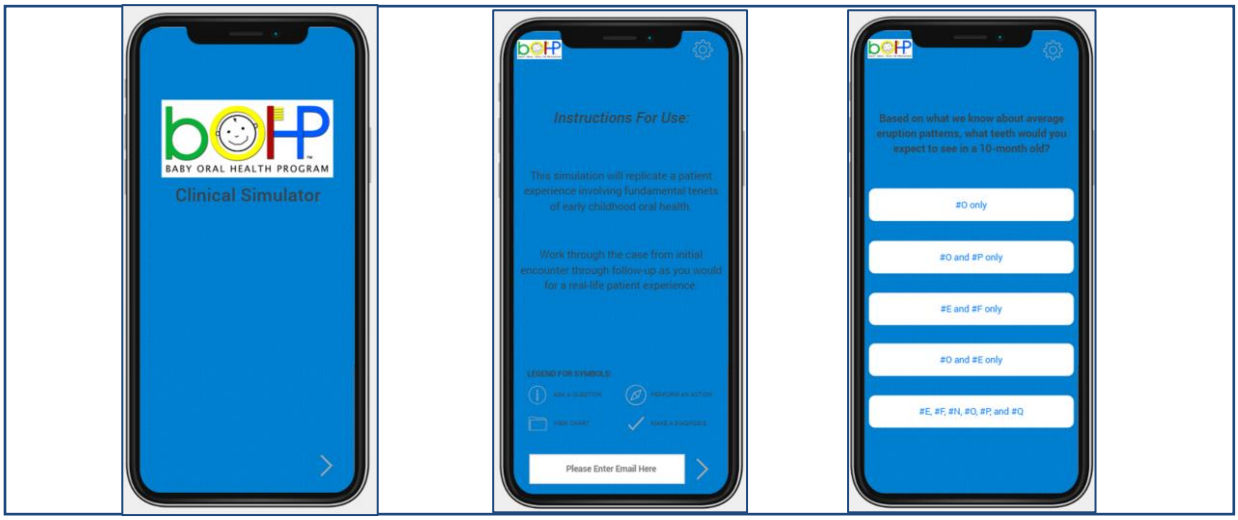
Planning Phase:

Blueprinting with Mindmap

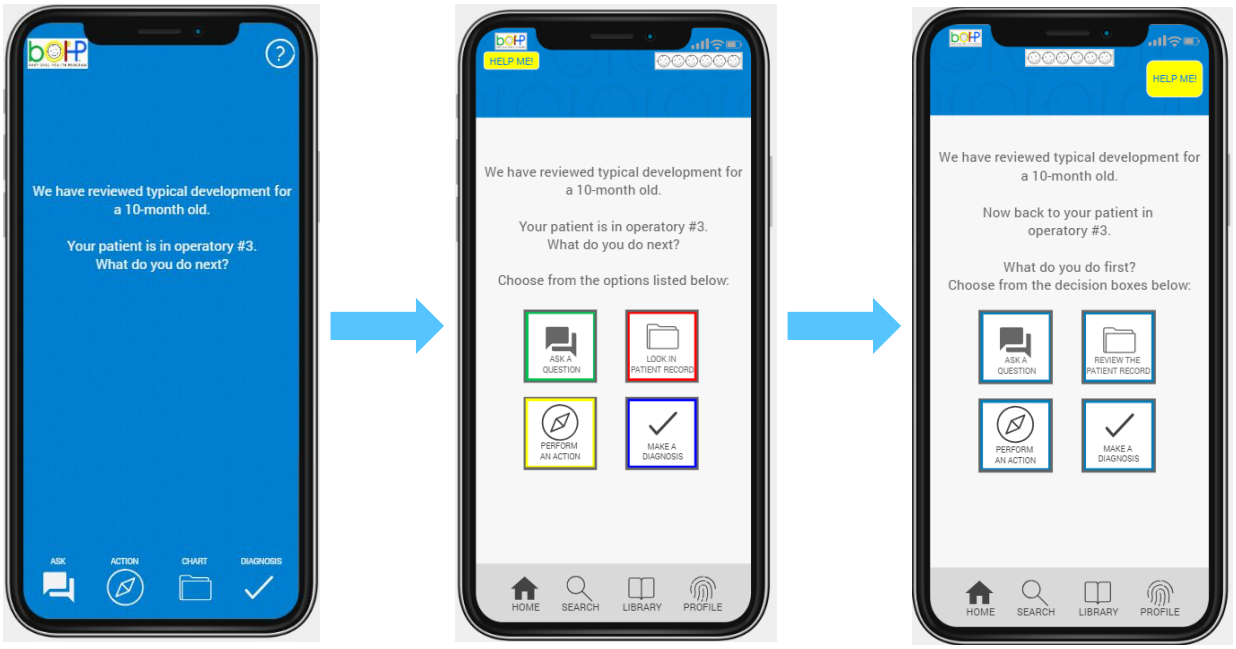


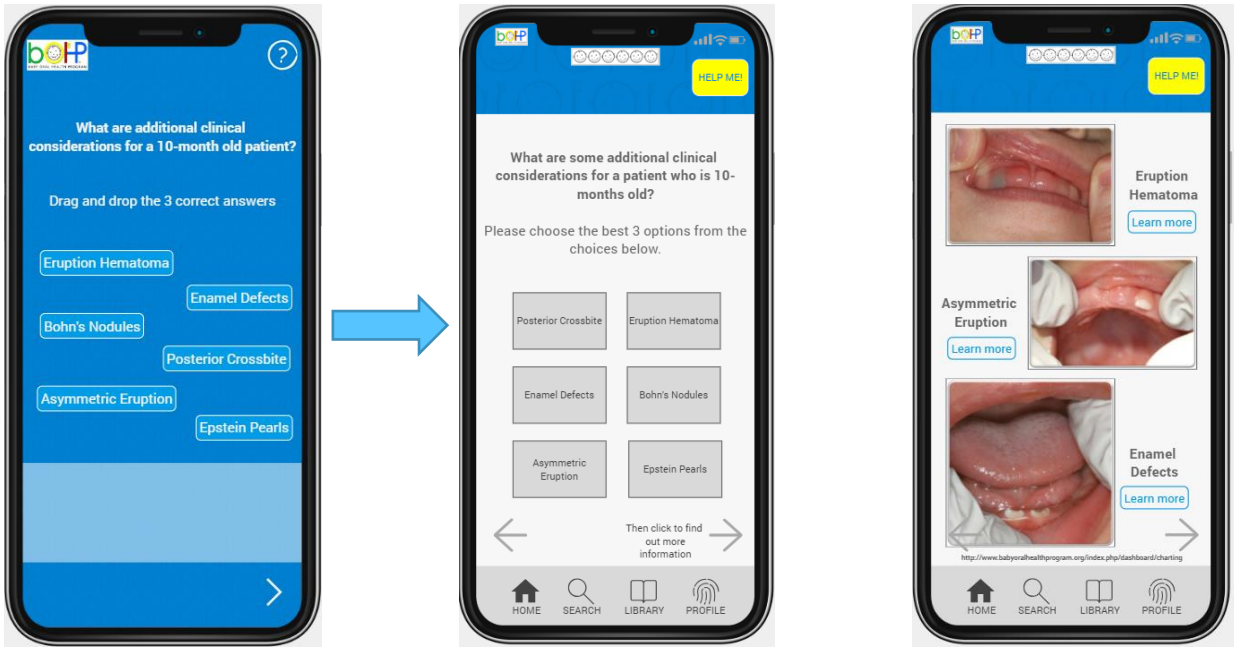
Prototyping Phase:

Initial Static Prototype Wireframes



Wireframe Evolution, Static Prototype to Interactive Prototype with Justinmind Prototyper Tool





The following are a list of references that appear within the smartphone application:

1. https://www.aapd.org/media/Policies_Guidelines/R_DentalGrowth.pdf

2. https://www.babyoralhealthprogram.org/

3. https://www.aapd.org/globalassets/media/policies_guidelines/bp_childabuse.pdf

4. McTigue D. Managing injuries to the primary dentition. Dent Clin NA 2009;53:627-638.

5. https://www.aapd.org/globalassets/media/policies_guidelines/r_acutetrauma.pdf

6. https://pocketdentistry.com/16-the-airway/

7. https://www.aapd.org/media/Policies_Guidelines/BP_OralSurgery.pdf

8. https://www.aapd.org/media/Policies_Guidelines/E_Injuries.pdf

9. Kennedy A, et al. Where is the tooth? Diagnosing and managing dentoalveolar injuries during infancy. Ann Pediatr Child Health; 2:1022.

10. Singh H, Parakh A. Tracheobronchial foreign body aspiration in children. Clin Pediatr 2014;53:415-419.

11. https://i.ebayimg.com/thumbs/images/g/6qQAAOSwYZ9ZnpQj/s-l225.jpg

12. https://www.chop.edu/conditions-diseases/throat-anatomy-and-physiology

13. https://universityhealthkc.org/images/ear-nose-throat/250/ENT-Obstructive-Sleep-Apnea-Surgical-Intervention.jpg

14. Kay M, Wyllie R. Pediatric foreign bodies and their management. Curr Gastroenterol Rep 2005;7:212-218.

15. Borum M, Andreasen J. Sequelae of trauma to primary maxillary incisors. I. Complications in the primary dentition. Endod Dent Traumatol 1998;14:31-44.

16. https://www.denteractive.com/dental-terms/

17. Malmgren B. et al. International Association of Dental Traumatology guidelines for the management of traumatic dental injuries 3. Injuries in the primary dentition. 2012; 28 : 174-182.

18. https://www.aapd.org/research/oral-health-policies--recommendations/Dental-Home/

19. Glendor U, Koucheki B, Halling A. Risk evaluation and type of treatment of multiple dental trauma episodes to permanent teeth. Endod Dent Traumatol 2000;16:205-210.

20. Avsar A, Topaloglu B. Traumatic tooth injuries to primary teeth of children age 0-3 years. Dental Traumatology 2009;25:323-327.

APPENDIX 2: INTERVIEW GUIDE FOR LEARNER TESTING
(IRB Study #: 18-0616)

Part 1: Prototype Development, Facilitator/Interview Guide for Learner Testing

NOTES:

- ISO (International Organization for Standardization)/IEC (International Electrotechnical Commission) 25010:2011 is a systems and software engineering standard that was last reviewed and confirmed in 2017.[1] The standard defines a product quality model and a quality in use model that is applicable to all software products and computer systems.[1] This standard establishes a quality model for software products and software-intensive systems that guides formulation of quality requirements and metrics to measure their satisfaction.[2] The product quality model addresses quality when software is in the development stage.[3] The primary concern of the quality in use model is quality when the software is used in the operation stage of its life cycle.[3] The definitions of characteristics and sub-characteristics that are used in this document are found within the ISO/IEC 25010 document.[4]

- The learner testing session is user-driven and the questions asked will be for clarification purposes.
- The facilitator will have a list of questions that could be asked but depending on the situation, the facilitator may not use all of the questions.
- Facilitator will let users know that prototype is not fully functioning.

TEST OBJECTIVES:
To determine usability of prototype by assessing the following characteristics:

Product Quality:

- **Functional Appropriateness:** degree to which the functions facilitate the accomplishment of specified tasks and objectives
- **Learnability:** degree to which the prototype enables the user to learn how to use it with effectiveness and efficiency
- **Operability:** degree to which the prototype is easy to operate, control and appropriate to use
- **User interface esthetics:** degree to which the user interface enables pleasing and satisfying interaction for the user

Quality in Use:

- **Effectiveness:** accuracy and completeness with which users achieve specified goals
- **Efficiency:** resources expended in relation to the accuracy and completeness with which users achieve goals
- **Usefulness:** degree to which a user is satisfied with their perceived achievement of pragmatic goals, including the results of use and the consequences of use

TEST QUESTIONS:

Pre-test open ended questions:

- We are developing an early childhood oral health educational instructional technique with the goal that it will be turned into a smartphone application in the future; what do you expect this prototype to look like?

- What is your preference for using technology within your dental school education and in particular, your early childhood oral health education?

- Will the use of an interactive prototype add value to your education?

- Before you look at the prototype, what do you expect to be able to do with it?

Questions that could be asked by facilitator during usability test:

- How did [x] help you learn [explain specific goals you want your target learners to learn]?

- While you were doing [x], what was going through your mind?

- You seemed confused here. Can you tell us more about that?

- Could you explain why you did [x]?

- What did you think it would do?

- If you could change one thing here to better help dental students [learning goal], what would that be?

Post-test open ended questions:

- Overall, what did you think about navigating around the prototype? (OPERAB)

- Did the set of functions implemented in this prototype facilitate the accomplishment of [specified user tasks and goals]? (F APPR)

- What did you feel about the way the prototype was organized? (OPERAB)

- Did you feel you could easily achieve [the specified learning goals] while using this prototype? (LEARN)

- Was the prototype easy to operate? (OPERAB)

- Did you feel the prototype was user-friendly? Can you tell us more about that? (OPERAB)

- Did the user interface enable a satisfying user interaction? (USER INTERF AESTH)

- Did the prototype line up with your expectations? (USEFULNESS)

- How satisfied were you with using this prototype? (USEFULNESS)

- Was the patient case presented in a way that was easy to understand? (EFFECTIVENESS)

- How many choices do you want to be given as the case unfolds? (EFFICIENCY)

- How long would your ideal early childhood oral health case take to complete? (EFFICIENCY)

- Would you like gaming elements to be incorporated into the prototype? (EFFECTIVENESS)

- Would you like the prototype to be competitive against other people? (USER INTERF)

- Would you like animation or video clips as opposed to static graphics or images? (LEARN)

- As you work through the early childhood oral health case, how often would you like to receive feedback (for instance, immediately, intermittently, at the end of the case)? (EFFECTIVENESS/USEFULNESS)

- When being linked to a reference, would you prefer the link be to the entire article or the specific concept within the article/guideline? (EFFICIENCY)

- Questions to get at attractiveness of the prototype (was the font size easy to read? Background, colors and graphics appropriate?) (USER INTERF AESTH)

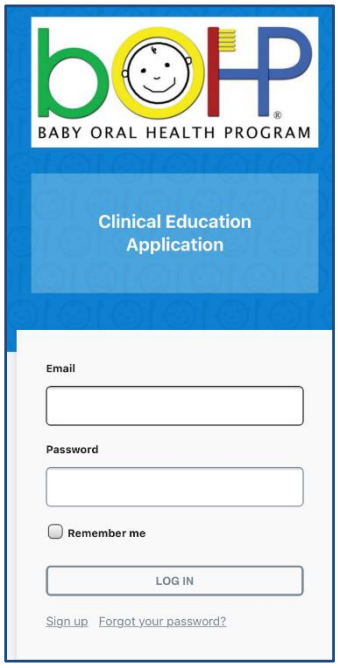
- What is your overall impression of the appearance of the prototype? (USER INTERF)

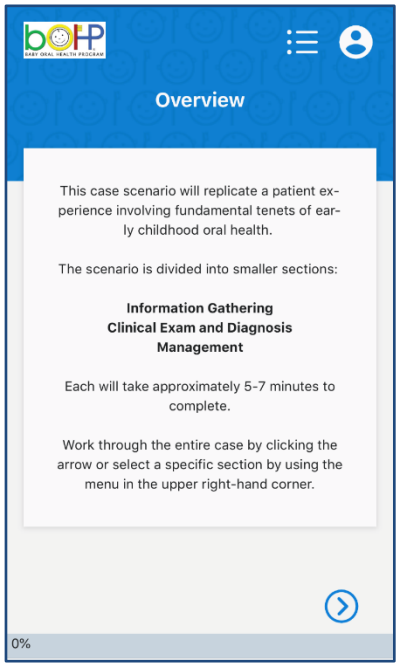
- Smart phone functionality, do you want only multiple choice? Drag and drop? Matching? Other? (USEFULNESS/EFFICIENCY)

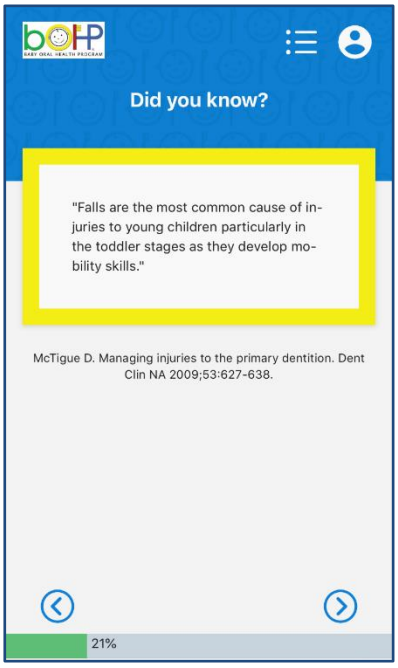
[1] https://www.iso.org/standard/35733.html
[2] Schneider, Florian, Berenbach, Brian. A literature Survey on International Standards for Systems Requiring Engineering. Procedia Computer Science. 2013; 16: 796-805.
[3] Garcia-Mireles, Gabriel Alberto. Identifying Relevant Product Quality Characteristics in the Context of Very Small Organizations. Computer Science and Information Systems. 2016; 13(3): 875-900.
[4] https://edisciplinas.usp.br/pluginfile.php/294901/mod_resource/content/1/ISO%2025010%20-%20Quality%20Model.pdf

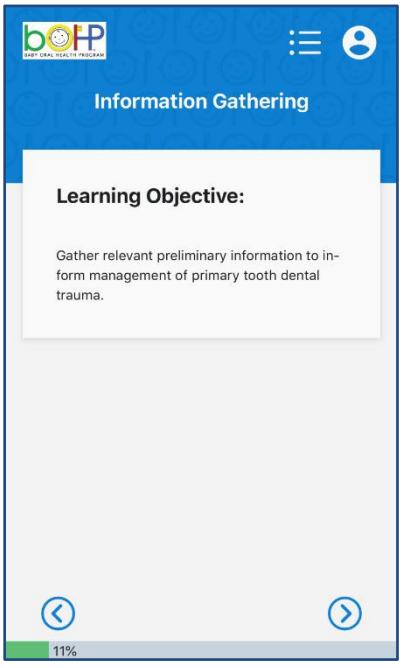
APPENDIX 3: bOHP CLINICAL EDUCATION APP

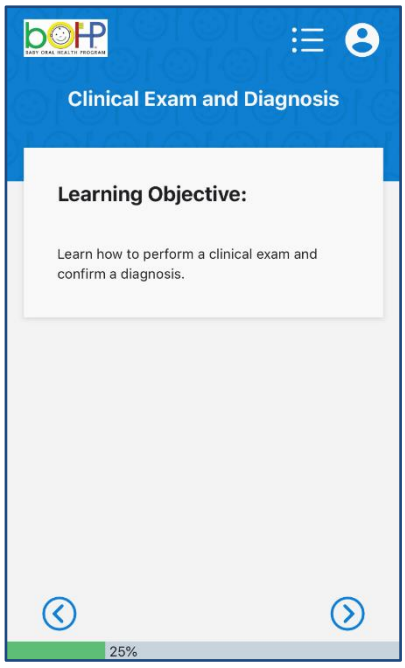
App Screen Examples:

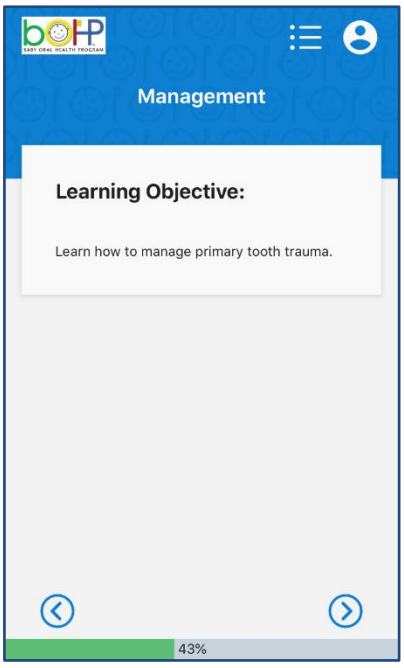


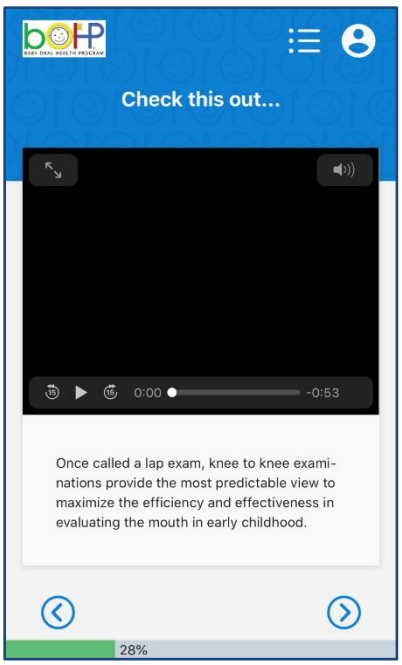


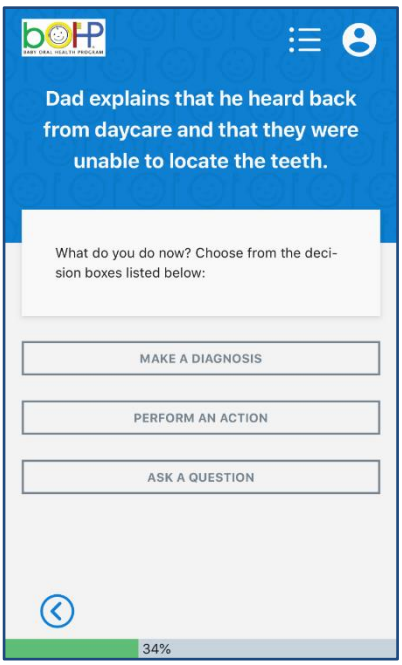


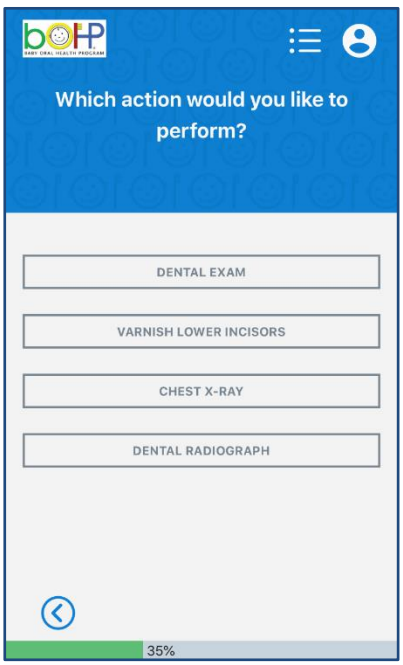


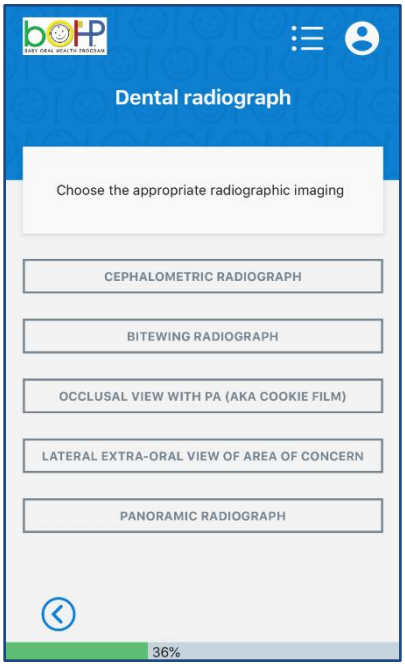


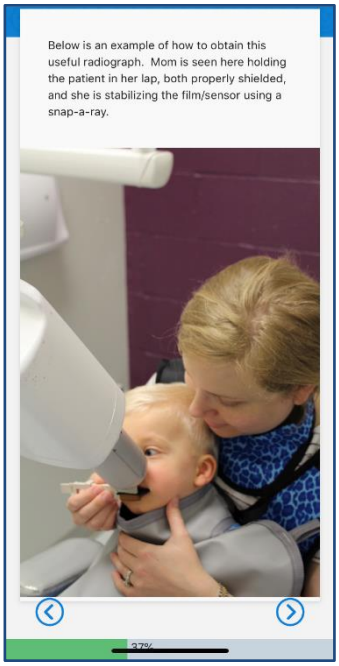



Check this out...
0:00
-0:53
Once called a lap exam, knee to knee examinations provide the most predictable view to maximize the efficiency and effectiveness in evaluating the mouth in early childhood.
28%


Dad explains that he heard back from daycare and that they were unable to locate the teeth.
What do you do now? Choose from the decision boxes listed below:
MAKE A DIAGNOSIS
PERFORM AN ACTION
ASK A QUESTION
34%

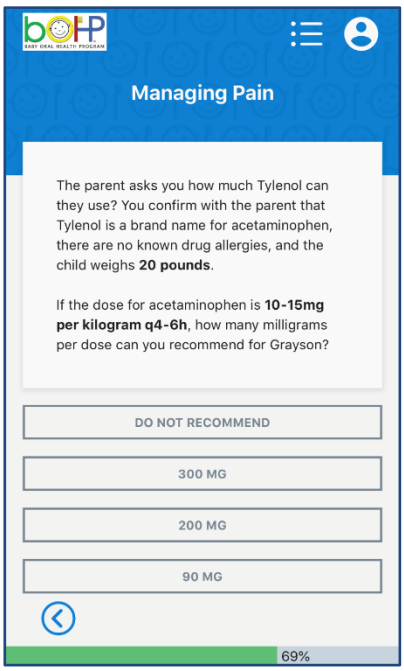

Which action would you like to perform?
DENTAL EXAM
VARNISH LOWER INCISORS
CHEST X-RAY
DENTAL RADIOGRAPH
35%

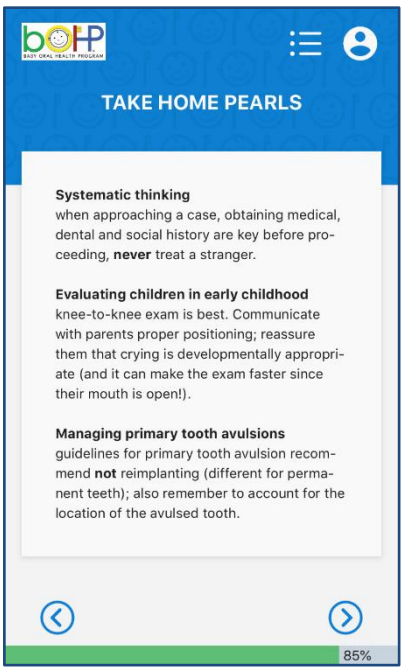

Dental radiograph
Choose the appropriate radiographic imaging
CEPHALOMETRIC RADIOGRAPH
BITEWING RADIOGRAPH
OCCLUSAL VIEW WITH PA (AKA COOKIE FILM)
LATERAL EXTRA-ORAL VIEW OF AREA OF CONCERN
PANORAMIC RADIOGRAPH
36%


Below is an example of how to obtain this useful radiograph. Mom is seen here holding the patient in her lap, both properly shielded, and she is stabilizing the film/sensor using a snap-a-ray.


This is the image you obtain. What do you see?
#8 AND #9 ARE DEVELOPING
MESIODENS
MISSING #E AND #F


Enamel hypoplasia and enamel discoloration are the most common sequelae
Other sequelae could be crown and/or root dilaceration or disturbance in eruption
Images courtesy of Martha Ann Keels, DDS, PhD


Managing Pain
The parent asks you how much Tylenol can they use? You confirm with the parent that Tylenol is a brand name for acetaminophen, there are no known drug allergies, and the child weighs **20 pounds**.
If the dose for acetaminophen is **10-15mg per kilogram q4-6h**, how many milligrams per dose can you recommend for Grayson?
DO NOT RECOMMEND
300 MG
200 MG
90 MG
69%


TAKE HOME PEARLS
Systematic thinking
when approaching a case, obtaining medical, dental and social history are key before proceeding, **never** treat a stranger.
Evaluating children in early childhood
knee-to-knee exam is best. Communicate with parents proper positioning; reassure them that crying is developmentally appropriate (and it can make the exam faster since their mouth is open!).
Managing primary tooth avulsions
guidelines for primary tooth avulsion recommend **not** reimplanting (different for permanent teeth); also remember to account for the location of the avulsed tooth.
85%

APPENDIX 4: SURVEY INSTRUMENTS

(IRB Study #: 18-0616)

(Pre-) Survey Instrument given to all participants:

Please indicate your response to the following statement by choosing one number on the Likert scale.

Please rate the value of an interactive smartphone application in your dental education.

No value 1	A little value 2	Some value 3	A lot of value 4

Please choose the best response to each question below:

Question #1

What are the three benefits to a patient seeing a medical doctor prior to you evaluating that patient after dental trauma?	
A: Get vaccinated, evaluate BMI, rule out concussion	C: Check vitals, obtain blood draw, get vaccinated
B: Discuss diet, evaluate BMI, check vitals	D: Complete neurological exam, check vitals, rule out concussion

Question #2

_____ is the most predictable way of obtaining an oral examination for infants/toddlers.	
A: Patient sitting upright	C: Knee to knee positioning
B: Recline patient with parent in dental chair	D: Stand in front of patient

Question #3

What primary tooth is most likely involved in dental trauma?	
A: Mandibular central incisor	C: Maxillary central incisor
B: Maxillary lateral incisor	D: Mandibular lateral incisor

Question #4

What are two common dental trauma sequelae that could occur from primary tooth trauma?	
A: Buccal frenal tear and internal resorption	C: Pulp canal obliteration and lip lacerations
B: Gingival ulcer and periapical pathology	D: Color change and pulp necrosis

Question #5

Which one of the following definitions* describes "avulsion"?	
A: An injury to the tooth supporting structures with increased mobility, but without displacement of the tooth. In acute trauma, bleeding from the gingival sulcus confirms the diagnosis.	C: Displacement of the tooth *other than axially*. Displacement accompanied by comminution or fracture of either the labial or the palatal/lingual alveolar bone.
B: Partial displacement of the tooth out of its alveolar socket	D: Complete displacement of the tooth out of its socket

*definitions taken from Dental Trauma Guide

Question #6

What is a peak age for dental trauma in the primary dentition?	
A: 6-9 months	C: 12-18 months
B: 2-3 years	D: 4-5 years

Question #7

_____ is one of the best predictors of trauma.	
A: A previous history of trauma	C: Overbite (OB) > 80%
B: Overjet (OJ) < 3mm	D: Mandibular prognathism

Question #8

What are the two most common long-term permanent tooth sequelae after a primary tooth has been avulsed?	
A: Enamel hypoplasia and enamel discoloration	C: Enamel discoloration and crown dilaceration
B: Root dilaceration and enamel hypoplasia	D: Disturbance in tooth eruption and crown dilaceration

Question #9

What factor could significantly influence why permanent successors are affected during primary tooth trauma?	
A: Supernumerary teeth are in the area	C: Stage of mineralization of permanent successor
B: Delayed follow up with the dentist	D: Inability to maintain hygiene after a traumatic injury

Question #10

What is the recommended timing for follow-up following a primary tooth avulsion over the course of the first 12 months?	
A: 1 week, 6 months, 1 year	C: 1 week, 6 weeks, 6 months, 1 year
B: 1 week, 3 months, 6 months, 9 months, 1 year	D: 1 week, 3 months, 9 months, 1 year

Please circle one response to each question below:

How comfortable do you think you would be with:

	Very Uncomfortable	Uncomfortable	Neither Uncomfortable nor Comfortable	Comfortable	Very Comfortable
obtaining a medical history?	1	2	3	4	5
obtaining a chief complaint?	1	2	3	4	5
assessing normal development /normal eruption?	1	2	3	4	5
performing a knee-to-knee exam?	1	2	3	4	5
a young crying patient in your dental chair?	1	2	3	4	5
knowing when to refer to a specialist?	1	2	3	4	5
diagnosing primary tooth dental trauma?	1	2	3	4	5
providing primary tooth trauma counseling?	1	2	3	4	5
knowing where to access up-to-date trauma guidelines?	1	2	3	4	5

Please rate your overall comfort in the following areas by circling one number for each domain:

	Very Uncomfortable	Uncomfortable	Neither Uncomfortable nor Comfortable	Comfortable	Very Comfortable
Information gathering	1	2	3	4	5
Clinical exam	1	2	3	4	5
Diagnosis of primary tooth trauma	1	2	3	4	5
Management of primary tooth trauma	1	2	3	4	5

Based on your current understanding of diagnosis and management of primary tooth trauma, would you refer a patient who had experienced primary tooth trauma to a specialist or treat the patient in your practice? If you would treat, please indicate on the scale below, your comfort with treating a patient with primary tooth trauma.

1	2	3	4	5	6	7	8	9	10

(Post-) Survey for Intervention Group Additional Questions assessing app utility & functionality:

Please circle one response to each statement below.

Please rate:

	Very difficult to operate	Difficult to operate	Neither difficult nor easy	Easy to operate	Very easy to operate
The smartphone application's performance.	1	2	3	4	5

	Definitely not user-friendly	Not user-friendly	Somewhat user-friendly	User-friendly	Definitely user-friendly
The user-friendliness of the smartphone application's interface.	1	2	3	4	5

	Very inappropriate	Inappropriate	Neither appropriate nor inappropriate	Appropriate	Very appropriate
The suitability of the images used in the smartphone application.	1	2	3	4	5
The overall appearance of the smartphone application.	1	2	3	4	5

	Definitely not useful	Not useful	Somewhat useful	Useful	Definitely useful
The usefulness of the educational content of the smartphone application.	1	2	3	4	5

	No value	A little value	Some value	A lot of value
The value of an interactive smartphone application in your dental education.	1	2	3	4

	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
The educational application deepened my interest in primary tooth trauma.	1	2	3	4	5
The educational application deepened my interest in early childhood oral health.	1	2	3	4	5

FUTURE DEVELOPMENT:

Do you feel that more of these types of cases spanning early childhood oral health would help/assist your education? YES NO

RECOMMENDATIONS FOR FUTURE CASES:

OPEN ENDED QUESTIONS:

What was the best thing about the smartphone application?

What can be done to make it better?

APPENDIX 5: SCRIPT CONCORDANCE TEST

(IRB Study #: 18-0616)

A Script Concordance Test (SCT) is a written case-based test used for assessing clinical reasoning under conditions of uncertainty. This SCT will ascertain your reasoning for primary tooth trauma cases that could occur in early childhood, with a focus on primary tooth avulsion.

Below are three case vignettes with associated questions. The questions will cover aspects of information gathering, clinical exam, diagnosis, and management domains. Within each case scenario, each item is <u>independent</u> of the others. This is important since the test is not assessing the additive effect of a series of clinical data, but determining the effect of a <u>single item of clinical information</u> on a hypothesis, action or treatment option. Each test item consists of three parts, represented in separate columns:

- first column includes a diagnostic hypothesis, investigative action, or treatment option that is relevant to the situation
- middle column presents new information that might have an impact on the hypothesis, action or treatment option
- last column is a 5-point Likert scale (key is located at the bottom of each box) to register your decision regarding the fit of the new information with the hypothesis/action/treatment option provided

CASE SCENARIO FOR QUESTIONS #1 to #7.

A 10-month-old presents to your general dental office with his parents. He fell earlier today at daycare. Mom and Dad tell you that he is missing his front teeth.

1:

If you were considering to ask if the patient:	**And then you find:**	**That plan becomes:**				
Was up-to-date on his DTaP vaccine	He has a severe milk allergy	-2	-1	0	+1	+2
Has achieved his developmental milestones	His parents are pediatricians	-2	-1	0	+1	+2
Had been seen by his pediatrician for medical check after his fall	Mom doesn't believe in western medicine	-2	-1	0	+1	+2
Has a non-nutritive habit	He has a linked habit, and uses both a pacifier and carries around a security blanket	-2	-1	0	+1	+2
-2: useless; -1: less useful; 0: neither more nor less useful; +1: useful; +2: very useful						

2:

If you were thinking of the following diagnosis and/or plan of care:	**And the following new information were to become available:**	**This hypothesis would become:**				
Adjacent or opposing teeth having uncomplicated crown fractures	Patient was born prematurely with a lower birth weight	-2	-1	0	+1	+2
Palatal luxation of maxillary primary laterals and monitoring given lack of mobility	Occlusal interference preventing the patient from biting down completely	-2	-1	0	+1	+2
Rinsing debris out of a lip laceration	Patient is not up-to-date with his DTaP	-2	-1	0	+1	+2
Aspiration of the avulsed tooth	Patient has had slight wheezing during breathing since this morning	-2	-1	0	+1	+2
-2: very unlikely; -1: unlikely; 0: neither likely nor unlikely; +1: more likely; +2: very likely						

3:

If you were considering the risk/benefit ratio of the following investigation:	**And the following new information were to become available:**	**The new information would make the investigation:**				
Obtaining a max occlusal radiograph	Parents report traumatized area of the mouth has not stopped bleeding	-2	-1	0	+1	+2
Performing a knee-to-knee exam	Parents faint at the sight of blood	-2	-1	0	+1	+2
Performing a knee-to-knee exam	The child has clear fluid coming out of his ear	-2	-1	0	+1	+2
Performing a knee-to-knee exam	The child has blood coming out of his nose	-2	-1	0	+1	+2
Obtaining a max occlusal radiograph	Parents inform you the child has a history of repeated medical CT scans	-2	-1	0	+1	+2
Obtaining a chest x-ray	Parents inform you the child has a history of having a hard time with sedation	-2	-1	0	+1	+2
Obtaining a cone beam CT (CBCT)	Parents would have to pay out of pocket for diagnostic imaging	-2	-1	0	+1	+2
Performing a knee-to-knee exam	Patient unable to recline fully	-2	-1	0	+1	+2
-2: strongly contraindicated; -1: contraindicated; 0: neither more nor less indicated; +1: indicated; +2: strongly indicated						

4:

If you were considering:	**And the caregiver reports OR you find upon clinical exam:**	**This plan becomes:**				
Obtaining a max occlusal film with parental help	That mom is pregnant	-2	-1	0	+1	+2
Obtaining a max occlusal film with parental help	The child vomited in his car seat on the drive to your office	-2	-1	0	+1	+2
Obtaining a chest x-ray for suspected ingestion of avulsed teeth	Tooth-like structure visible intra-orally at crest of alveolar ridge	-2	-1	0	+1	+2
Monitoring patient at home for respiratory signs/symptoms and having parents check patient's stools	Parents inform you they have a weak stomach and can't sift through poopy diapers	-2	-1	0	+1	+2
Obtaining a lateral extra-oral radiograph	Mom is a licensed but non-practicing dentist who brought the avulsed teeth in cold milk	-2	-1	0	+1	+2
Confirming timing and history of injury	Different variations on history depending on what parent you ask	-2	-1	0	+1	+2
-2: ruled out/almost ruled out; -1: less likely; 0: neither more nor less likely; +1: more likely; +2: certain/almost certain						

5:

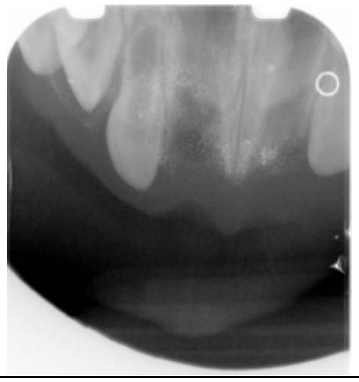
The knee-to-knee exam reveals this:

If you were thinking of the following diagnosis:	**And the following new information were to become available:**	**This hypothesis would become:**				
Intrusion	Tooth fragments found on site	-2	-1	0	+1	+2
Avulsion	The teeth were not located on site	-2	-1	0	+1	+2
Ingestion	Patient has a paroxysmal* cough	-2	-1	0	+1	+2
-2: very unlikely; -1: unlikely; 0: neither likely nor unlikely; +1: more likely; +2: very likely						

*definition of paroxysmal cough: frequent and violent coughing that can make it hard for a person to breathe

6:

Your radiographic exam reveals this:



If you were thinking of the following diagnosis:	**And the following new information were to become available:**	**This hypothesis would become:**
Ingestion	Child has a history of constipation	-2 -1 0 +1 +2
Aspiration	One tooth was found on site	-2 -1 0 +1 +2

-2: very unlikely; -1: unlikely; 0: neither more nor less likely; +1: more likely; +2: very likely

7:

If you were considering to prescribe:	**And then you find:**	**That prescription becomes:**
An antibiotic	A dirty lip laceration	-2 -1 0 +1 +2
Acetaminophen	Patient was born at 32 weeks gestation	-2 -1 0 +1 +2
Nonsteroidal anti-inflammatory drug (NSAID)	Patient has a reactive airway	-2 -1 0 +1 +2

-2: strongly contraindicated; -1: contraindicated; 0: neither more nor less indicated; +1: indicated; +2: strongly indicated

CASE SCENARIO FOR QUESTIONS #8 & #9

A 10-month-old presents with his parents to your general dental office for follow-up one week after avulsing #E and #F.

8:

If you were thinking of:	**And then you find:**	**This plan becomes:**				
Referring for radiographic (*CXR, KUB) imaging	Tooth fragments in patient's diaper	-2	-1	0	+1	+2
Monitoring because the area should be healing by now	White area in the sockets	-2	-1	0	+1	+2
-2: ruled out/almost ruled out; -1: less likely; 0: neither more nor less likely; +1: more likely; +2: certain/almost certain						

*CXR, KUB: chest x-ray; kidneys, ureter, and bladder x-ray

9:

If you were considering:	**And the caregiver reports OR you find upon clinical exam:**	**This plan becomes:**				
Doing a clinical exam	Since his fall at daycare his separation anxiety has gotten more pronounced	-2	-1	0	+1	+2
Counseling on future trauma prevention	Purplish-blue swelling in the area of the primary lateral incisors	-2	-1	0	+1	+2
Counseling on future trauma prevention	Asymmetric eruption of his lateral incisors	-2	-1	0	+1	+2
-2: ruled out/almost ruled out; -1: less likely; 0: neither more nor less likely; +1: more likely; +2: certain/almost certain						

CASE SCENARIO FOR QUESTION #10

A 3-year-old presents to your general dental office with his parents. He fell earlier today at pre-school. His front teeth are missing.

10:

Your initial intention is to ask if patient:	**And then the caregiver reports:**	**That plan becomes:**				
Lost consciousness at the scene	The fall was unwitnessed	-2	-1	0	+1	+2
Was up to date with his tetanus	They don't believe in vaccines	-2	-1	0	+1	+2
Has been to the dentist before	He fell when he was a toddler and hit his mouth on the edge of the bathtub	-2	-1	0	+1	+2
-2: useless; -1: less useful; 0: neither more nor less useful; +1: useful; +2: very useful						

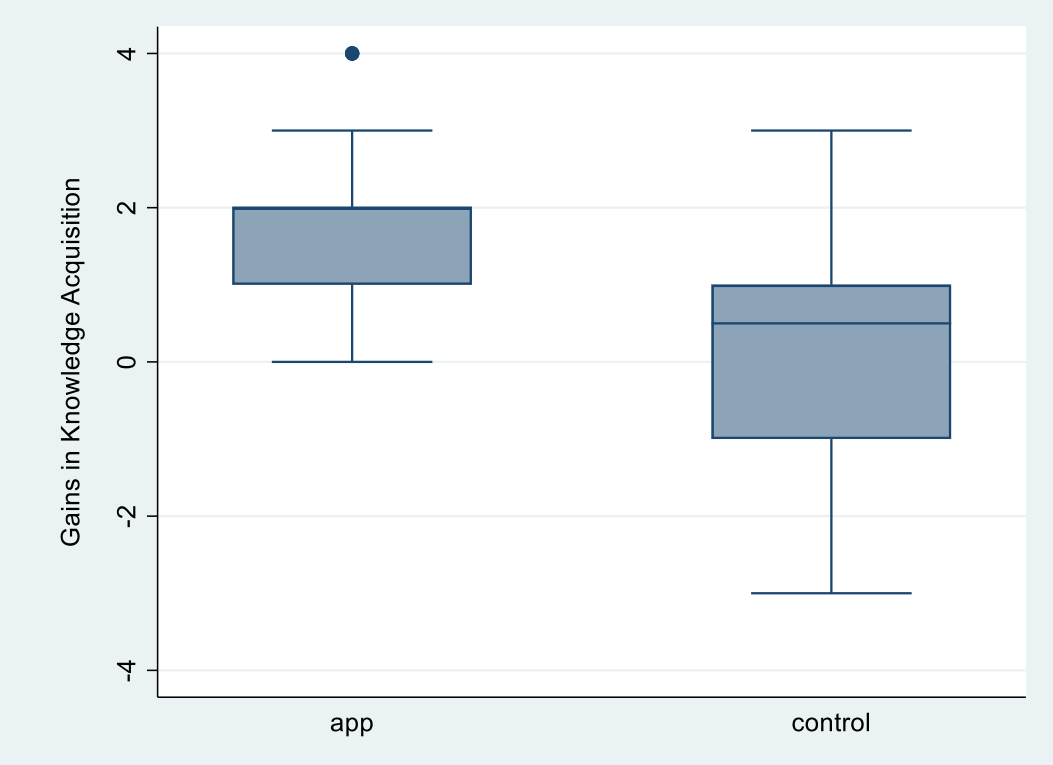
CASE SCENARIO FOR QUESTION #11

A 3-year-old presents with his parents to your general dental office for follow-up one week after avulsing #E and #F.

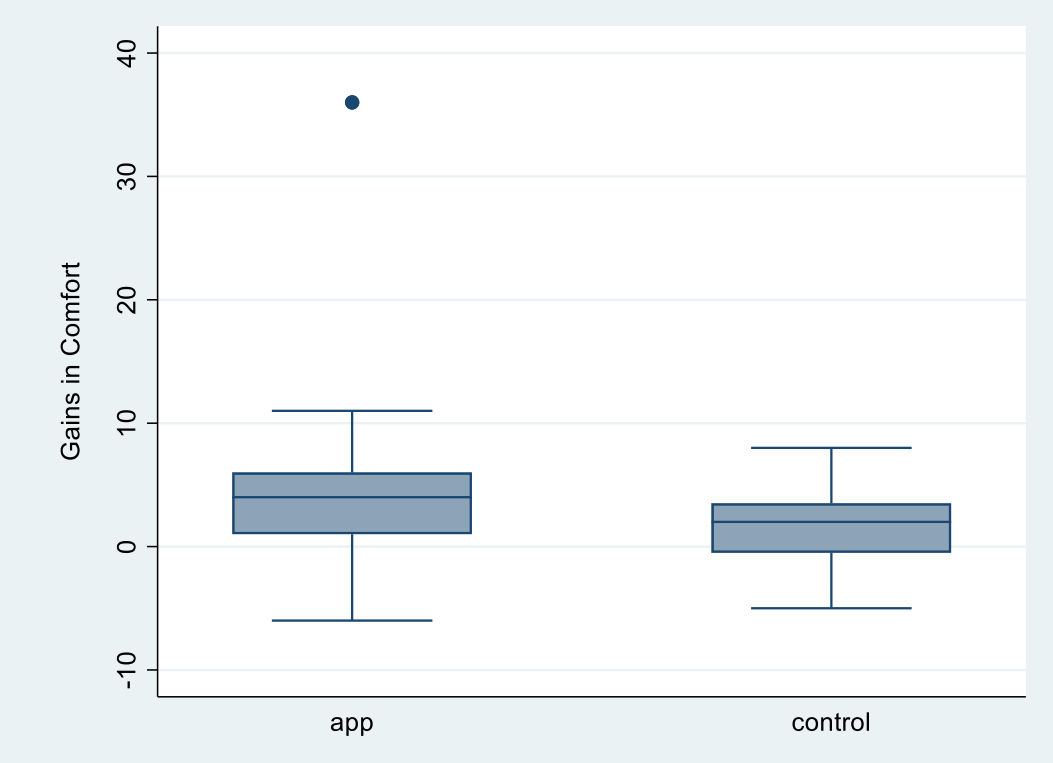
11:

If you were thinking of:	**And then you find:**	**This plan becomes:**				
Fabricating a pediatric partial denture (pedi-partial) due to impending future anterior space loss	Patient has an active pacifier/thumb habit	-2	-1	0	+1	+2
Counseling on future trauma prevention	Adjacent primary teeth appear grey from the lingual aspect	-2	-1	0	+1	+2
Advocating for regular dental care and establishment of dental home	Child has two older siblings (ages 5 and 7) who have never received regular dental care	-2	-1	0	+1	+2
-2: ruled out/almost ruled out; -1: less likely; 0: neither more nor less likely; +1: more likely; +2: certain/almost certain						

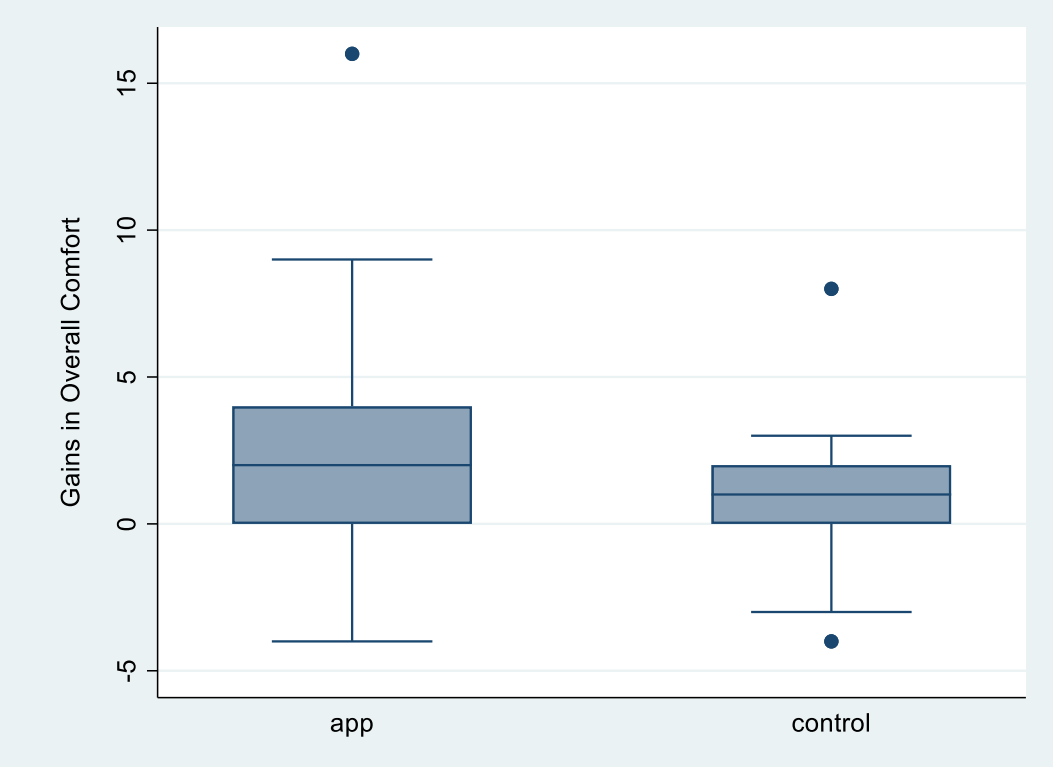
APPENDIX 6: SUPPLEMENTAL FIGURES



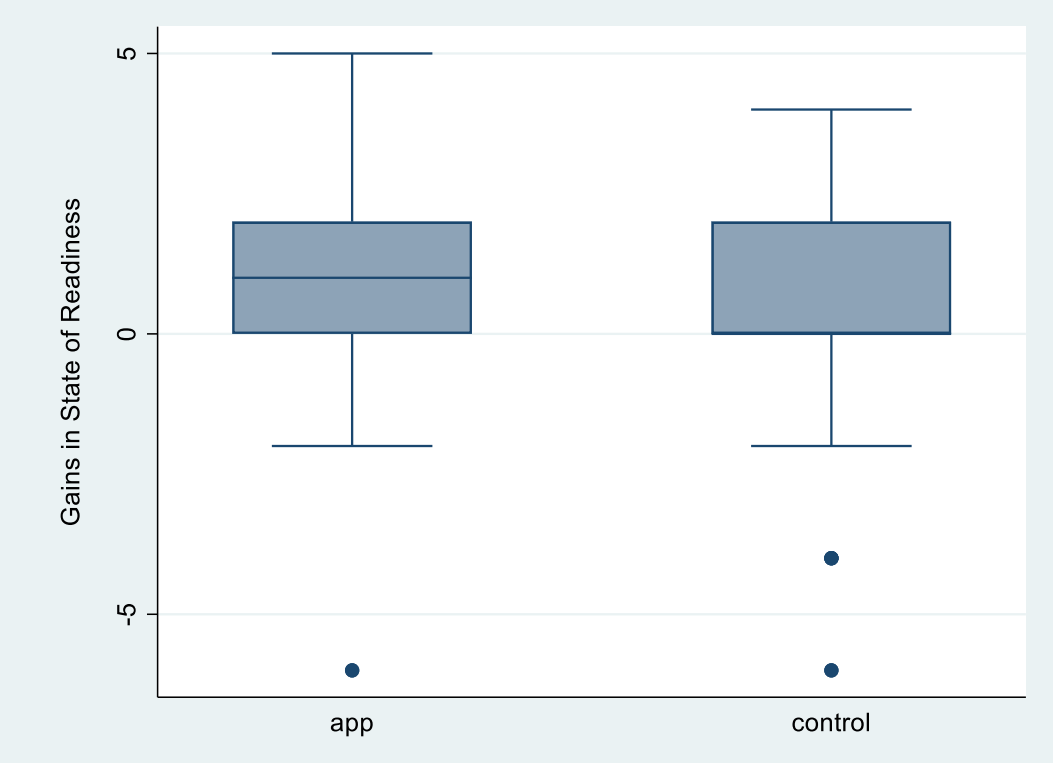
Supplemental Figure 1: Gains in Knowledge Acquisition stratified by experimental study group



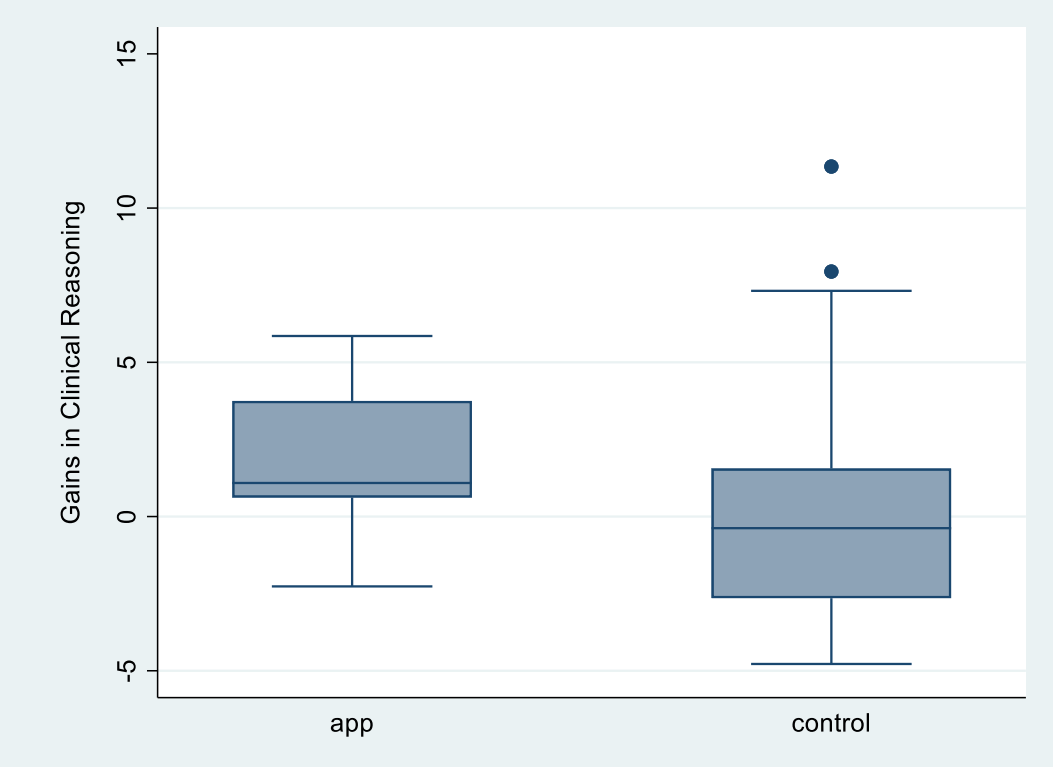
Supplemental Figure 2: Gains in Comfort stratified by experimental study group



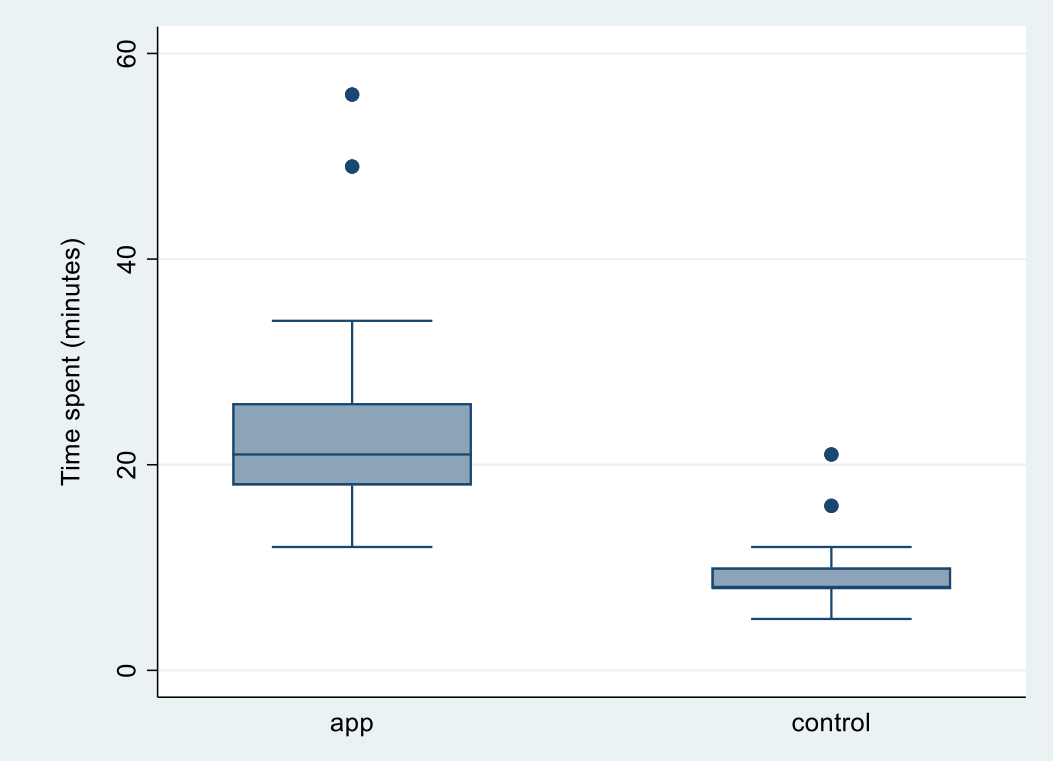
Supplemental Figure 3: Gains in Overall Comfort stratified by experimental study group



Supplemental Figure 4: Gains in State of Readiness stratified by experimental study group



Supplemental Figure 5: Gains in Clinical Reasoning stratified by experimental study group



Supplemental Figure 6: Time spent interacting with app in intervention group or reading the article in the control group

REFERENCES

1. Perinatal and infant oral health care. Pediatr Dent 2017;39(6):208–212.

2. Oral Health Assessment Policy [Internet]. [cited 2018 Feb 21];Available from: http://www.aaphd.org/oral-health-assessment-policy

3. Statement on Early Childhood Caries [Internet]. [cited 2018 Feb 21];Available from: https://www.ada.org/en/about-the-ada/ada-positions-policies-and-statements/statement-on-early-childhood-caries

4. Section On Oral Health. Maintaining and improving the oral health of young children. Pediatrics 2014;134(6):1224–1229.

5. American Academy on Pediatric Dentistry Council on Clinical Affairs. Policy on the Dental Home. Pediatr Dent 2018;40(6):29–30.

6. Howden LM, Meyer JA. Reproduction of the Questions on Sex, Age, and Date of Birth From the 2010 Census [Internet]. United States: U.S. Census Bureau; 2011 [cited 2018 Feb 21]. Available from: https://www.census.gov/prod/cen2010/briefs/c2010br-03.pdf

7. Professionally Active Dentists by Specialty Field | The Henry J. Kaiser Family Foundation [Internet]. [cited 2018 Feb 22];Available from: https://www.kff.org/other/state-indicator/dentists-by-specialty-field/?currentTimeframe=0&selectedRows=%7B%22wrapups%22:%7B%22united-states%22:%7B%7D%7D,%22states%22:%7B%22north-carolina%22:%7B%7D%7D%7D&sortModel=%7B%22colId%22:%22Pedodontist%22,%22sort%22:%22desc%22%7D

8. Garg S, Rubin T, Jasek J, Weinstein J, Helburn L, Kaye K. How willing are dentists to treat young children? The Journal of the American Dental Association 2013;144(4):416–425.

9. Rich JP, Straffon L, Inglehart MR. General dentists and pediatric dental patients: the role of dental education. J Dent Educ 2006;70(12):1308–1315.

10. Dao LP, Zwetchkenbaum S, Inglehart MR. General dentists and special needs patients: does dental education matter? J Dent Educ 2005;69(10):1107–1115.

11. Smith CS, Ester TV, Inglehart MR. Dental education and care for underserved patients: an analysis of students' intentions and alumni behavior. J Dent Educ 2006;70(4):398–408.

12. Vishnevetsky A, Mirman J, Bhoopathi V. Effect of advocacy training during dental education on pediatric dentists' interest in advocating for community water fluoridation. J Dent Educ 2018;82(1):54–60.

13. Price C. Why Don’t My Students Think I'm Groovy?: The New “R”s for Engaging Millennial Learners. In: Meyers SA, Stowell JR, editors. Essays from e-xcellence in teaching. 2010. p. 29–34.

14. Millennials: Confident. Connected. Open to Change | Pew Research Center [Internet]. [cited 2018 Apr 19];Available from: http://www.pewsocialtrends.org/2010/02/24/millennials-confident-connected-open-to-change/

15. Skiba DJ, Barton AJ. Adapting your teaching to accommodate the net generation of learners. Online J Issues Nurs 2006;11(2):5.

16. Stuart G, Triola M. Enhancing Health Professions Education through Technology: Building a Continuously' ' Learning Health System. In: Larson T, editor. Proceedings of a conference sponsored by the Josiah Macy Jr. Foundation in April 2015. New York: Josiah Macy Jr. Foundation; 2015.

17. Fontana M, González-Cabezas C, de Peralta T, Johnsen DC. Dental education required for the changing health care environment. J Dent Educ 2017;81(8):eS153–eS161.

18. Commission on Dental Accreditation. Accreditation Standards For Dental Education Programs. 2018:1–38.

19. Global Forum on Innovation in Health Professional Education, Board on Global Health, Institute of Medicine, National Academies of Sciences, Engineering, and Medicine. Envisioning the future of health professional education: workshop summary. Washington (DC): National Academies Press (US); 2016.

20. About bOHP [Internet]. [cited 2018 May 10];Available from: http://www.babyoralhealthprogram.org/index.php/about/page/11/Why+bOHP

21. Medical Home Initiatives for Children with Special Needs Project Advisory Committee. American Academy of Pediatrics. The medical home. Pediatrics 2002;110(1 Pt 1):184–186.

22. American Academy of Pediatrics Council on Children with Disabilities. Care coordination in the medical home: integrating health and related systems of care for children with special health care needs. Pediatrics 2005;116(5):1238–1244.

23. Britton CV, American Academy of Pediatrics Committee on Pediatric Workforce. Ensuring culturally effective pediatric care: implications for education and health policy. Pediatrics 2004;114(6):1677–1685.

24. Nowak AJ, Casamassimo PS. The dental home: a primary care oral health concept. J Am Dent Assoc 2002;133(1):93–98.

25. Seale NS, Casamassimo PS. Access to dental care for children in the United States: a survey of general practitioners. J Am Dent Assoc 2003;134(12):1630–1640.

26. Long CM, Quinonez RB, Rozier RG, Kranz AM, Lee JY. Barriers to Pediatricians' Adherence to American Academy of Pediatrics Oral Health Referral Guidelines: North Carolina General Dentists' Opinions. Pediatric Dentistry 2014;36(4):309–315.

27. McQuistan MR, Kuthy RA, Damiano PC, Ward MM. General dentists' referral of children younger than age 3 to pediatric dentists. Pediatr Dent 2005;27(4):277–283.

28. Casamassimo PS, Seale NS. Adequacy of patient pools to support predoctoral students' achievement of competence in pediatric dentistry in U.S. dental schools. J Dent Educ 2015;79(6):644–652.

29. Seale NS, Casamassimo PS. U.S. predoctoral education in pediatric dentistry: its impact on access to dental care. J Dent Educ 2003;67(1):23–30.

30. Rutkauskas J, Seale NS, Casamassimo P, Rutkauskas JS. Preparedness of Entering Pediatric Dentistry Residents: Advanced Pediatric Program Directors' and First-Year Residents' Perspectives. J Dent Educ 2015;79(11):1265–1271.

31. Bailit H, Formicola A. Introduction to "advancing dental education in the 21st century" project. J Dent Educ 2017;81(08):1004–1007.

32. Mangold K. Educating a New Generation: Teaching Baby Boomer Faculty About Millennial Students. Nurse Educ 2007;32(1):21–23.

33. Major JAH. Beyond the blackboard: Basics of generational learning. Surgical services management 2002;8(3):51.

34. Blue C, Henson H. Millennials and dental education: utilizing educational technology for effective teaching. J Dent Hyg 2015;89 Suppl 1:46–47.

35. Pastorino E. Chapter 4: When Generations Collide in the Classroom. In: Saville B, Zinn T, Meyers S, Stowell J, editors. Essays from E-xcellence in Teaching, 2006. Society for the Teaching of Psychology Web site: http://teachpsych.org/resources/ebooks/eit2006/eit2006.php: 2007. p. 16–19.

36. Millennials in Adulthood | Pew Research Center [Internet]. [cited 2018 Apr 19];Available from: http://www.pewsocialtrends.org/2014/03/07/millennials-in-adulthood/

37. Kneebone R. Simulation in surgical training: educational issues and practical implications. Med Educ 2003;37(3):267–277.

38. Cook DA, Hamstra SJ, Brydges R, et al. Comparative effectiveness of instructional design features in simulation-based education: systematic review and meta-analysis. Med Teach 2013;35(1):e867–898.

39. Cook DA, Hatala R, Brydges R, et al. Technology-enhanced simulation for health professions education: a systematic review and meta-analysis. JAMA 2011;306(9):978–988.

40. Cook DA, Brydges R, Hamstra SJ, et al. Comparative effectiveness of technology-enhanced simulation versus other instructional methods: a systematic review and meta-analysis. Simul Healthc 2012;7(5):308–320.

41. Ali A, Alrasheedi M, Ouda A, Capretz LF. A Study of The Interface Usability Issues of Mobile Learning Applications for Smart Phones from the User's Perspective. IJITE 2014;3(4):1–16.

42. What Are The Various Phases Of Mobile App Development? [Internet]. [cited 2020 Mar 10];Available from: https://medium.com/swlh/what-are-the-various-phases-of-mobile-app-development-4f0a1748e619

43. Mobile App Development Process: A Step-by-Step Guide | Invonto [Internet]. [cited 2020 Mar 10];Available from: https://www.invonto.com/insights/mobile-app-development-process/

44. García-Mireles G. Identifying relevant product quality characteristics in the context of very small organizations. ComSIS 2016;13(3):875–900.

45. Schneider F, Berenbach B. A literature survey on international standards for systems requirements engineering. Procedia Computer Science 2013;16:796–805.

46. Suitability F. Product Quality - ISO/IEC 25010 [Internet]. [cited 2018 Jul 1];Available from: https://edisciplinas.usp.br/pluginfile.php/294901/mod_resource/content/1/ISO%2025010%20-%20Quality%20Model.pdf

47. How to Conduct Usability Testing for Mobile Apps [Internet]. [cited 2020 Mar 23];Available from: https://www.abtasty.com/blog/usability-mobile-apps/

48. Mobile App Testing is Key to Successful App Development [Internet]. [cited 2020 Mar 23];Available from: https://usabilitygeek.com/usability-testing-mobile-applications/

49. Lubarsky S, Dory V, Duggan P, Gagnon R, Charlin B. Script concordance testing: from theory to practice: AMEE guide no. 75. Med Teach 2013;35(3):184–193.

50. Kennedy A, Quinonez R, Sanzone L, Pickens E. Where is the Tooth? Diagnosing and Managing Dentoalveolar Injuries During Infancy. Ann Pediatr Child Health 2014;2(3):1022.

51. MindMup [Internet]. [cited 2020 Jan 27];Available from: https://www.mindmup.com/

52. Wireframe vs Mockup vs Prototype , What's the Difference?(2020 Updated) [Internet]. [cited 2020 Jan 27];Available from: https://www.mockplus.com/blog/post/wireframe-mockup-prototype-selection-of-prototyping-tools

53. Free prototyping tool for web & mobile apps - Justinmind [Internet]. [cited 2020 Jan 27];Available from: https://www.justinmind.com/

54. David R. K. A Revision of Bloom's Taxonomy: An Overview. Theory of Practice 2002;41(4):212–218.

55. Dory V, Gagnon R, Vanpee D, Charlin B. How to construct and implement script concordance tests: insights from a systematic review. Med Educ 2012;46(6):552–563.

56. Shaw CM, Tan SA. Integration of mobile technology in educational materials improves participation: creation of a novel smartphone application for resident education. J Surg Educ 2015;72(4):670–673.

57. Bastawrous A, Cheeseman RC, Kumar A. iPhones for eye surgeons. EYE 2012;26(3):343–354.

58. Zvornicanin E, Zvornicanin J, Hadziefendic B. The Use of Smart phones in Ophthalmology. Acta Inform Med 2014;22(3):206–209.

59. O'Connor S, Andrews T. Smartphones and mobile applications (apps) in clinical nursing education: A student perspective. Nurse Educ Today 2018;69:172–178.

60. Deshpande S, Chahande J, Rathi A. Mobile learning app: A novel method to teach clinical decision making in prosthodontics. Educ Health (Abingdon) 2017;30(1):31–34.

61. bOHP [Internet]. [cited 2020 Feb 1];Available from: https://www.babyoralhealthprogram.org/

62. Gagnon R, Charlin B, Lambert C, Carrière B, Van der Vleuten C. Script concordance testing: more cases or more questions? Adv Health Sci Educ Theory Pract 2009;14(3):367–375.